AD-A141 099 STAGE I PROPELLANT SURVEILLANCE REPORT GLACIAL ACRYLIC ACID MOTORS GAA-00.. (U) OGDEN AIR LOGISTICS CENTER HILL AFB UT PROPELLANT ANALYSIS LA.. J A THOMPSON APR 84 1/1

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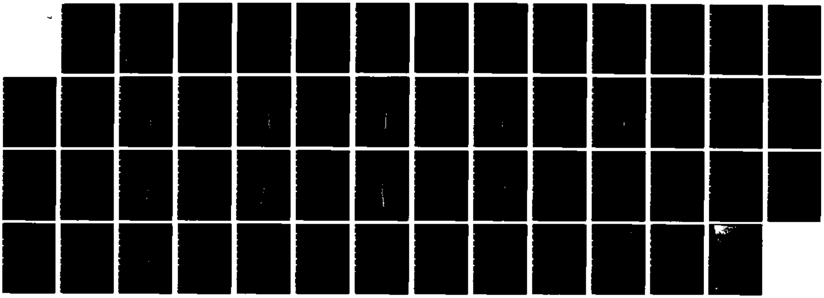

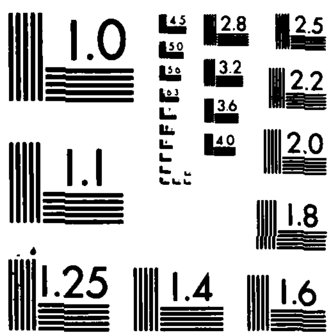


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

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UNITED STATES AIR FORCE
HILL AIR FORCE BASE, UTAH 84056

AD-A141 099

# STAGE I PROPELLANT SURVEILLANCE REPORT GLACIAL ACRYLIC ACID MOTORS GAA-001 AND GAA-002 TP-H1011 (FINAL REPORT)

PROPELLANT ANALYSIS LABORATORY

MANPA REPORT
NR 497(84)





April 1984

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MANPA REPORT NR 497(84)

# PROPELLANT SURVEILLANCE REPORT

# PROPELLANT CONTAINING GLACIAL ACRYLIC ACID

# MOTORS GAA-001 AND GAA-002

(FINAL REPORT)


Author

John A. Thompson

JOHN A. THOMPSON, Chemist
Component & Combustion Test Unit

Statistical Review By

Dan L. Petersen

DAN L. PETERSEN, Mathematician
Data Analysis Unit

Engineering Review By

John K Scambia

JOHN K. SCAMBIA, Project Engineer
Service Engineering

Approved By

Anthony J. Inverso

ANTHONY J. INVERSO, Chief
Propellant Analysis Laboratory



April 1984



Ind Prod & Ldg Gear Division
Directorate of Maintenance
Ogden Air Logistics Center
United States Air Force
Hill Air Force Base, Utah 84056

## ABSTRACT


Thiokol Minuteman First Stage propellant used acrylic acid to produce the HB polymer used as the binder. The original supplier of acrylic acid stopped production and Thiokol then obtained acrylic acid produced by the Taft, Louisiana Plant of Union Carbide Company (UCC).

To assure that this new source of supply was a satisfactory replacement, Thiokol* ran qualification testing on the new material and found it satisfactory. In the Thiokol* program two motors were cast in 1971 and propellant from the mixes were cast into cartons for a ten year test program. This propellant was then transferred to this laboratory and testing on a yearly basis was started in 1975.

Due to insufficient propellant, the full ten year program was not possible. Testing was completed after nine years and this is the final report.

From an analysis of the data the propellant's physical properties are satisfactory and the stability, with respect to age, is satisfactory.


*Final report evaluation of HB polymer manufactured using Taft glacial acrylic acid. Report number TWR-4716, May 1972. Thiokol/Wasatch Division, a division of Thiokol Chemical Corporation.

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## INTRODUCTION

### A. PURPOSE:

The purpose of this report is to compare physical data from glacial acrylic acid propellant used in the production of motors GAA-001 and GAA-002 with LGM-30F & G (TP-H1011) propellant data, and to assure that the modulus from the low rate testing is at least 550 psi @ 2.0 in/min and 77°F, and to evaluate the data to assure satisfactory propellant performance now and in the future.

### B. BACKGROUND

Minuteman Stage I rocket motors used TP-H1011 type propellant in the main grain. The binder system used in these propellants consists of controlled amounts of HB polymer and epoxy resin. The ratio of HB polymer/epoxy resin depends on stoichiometry of the polymers and also on the type and amount of impurities contained in the polymer. From past experience, the propellant mechanical and ballistic properties have been influenced by these impurities. Many impurities have been traced to the original raw materials, especially to the acrylic acid monomers. Aqueous acrylic acid is a product of the Institute, West Virginia, Union Carbide Company (UCC) plant and was used for eight years. UCC then announced that aqueous acid production had stopped and a monomer, glacial acrylic acid was being produced in their Taft, Louisiana plant.

This change necessitated the selection and verification of a new monomer.

This required: (1) preliminary evaluation of polymers made from existing glacial acids, (2) detailed evaluation of an immediately available acid source, (3) screening of polymers made using glacial acid from the candidate vendors including the new Taft material, and (4) final verification of the selected material,

The HB polymer, made from Taft glacial acrylic acid monomer, produced propellant that met the requirements of the verification program.

Two full scale motors were cast using glacial acrylic acid HB polymer (Motors GAA-001 & GAA-002). Forty-six one-half gallon cartons of propellant were cast in conjunction with these motors on 12-14 Jan 1971. Table 1 contains the test methods used for test period.

Regressions were plotted using the acrylic acid test data. These regressions are discussed and compared statistically to LGM-30 F & G regressions. The LGM-30 F & G regressions are included with the respective acrylic acid regressions for visual inspection. The modulus requirement for the 2.0 in/min at 77° F test data is discussed in the low rate tensile testing section.

It should be noted that in the discussion of test results it is often stated that test points are within a particular confidence band on the regression analysis. The word point refers to the mean of a particular group of data. The individual data that were used to comprise that mean are of course grouped around the mean. The standard deviation associated with each mean can be used to estimate where the extreme data spread would be with relation to the confidence bands.

## STATISTICAL ANALYSIS

Regression analysis data pertaining to propellant having glacial acrylic acid used in its manufacture has been statistically compared to regression data pertaining to standard TP-H1011 F and G propellant. Table 2 contains the results obtained in comparing 18 sets of regression slopes. Those comparisons that showed their slopes to be not significantly different were again compared to determine whether their intercepts (or elevations) were different, see Table 3. Only cohesive energy, a tear energy parameter, was found to be the same in slope and intercept to that of standard TP-H1011 F and G propellant.

Acrylic acid regression plots were made for each test parameter and can be visually compared to their corresponding standard TP-H1011 F and G plots. Emphasis is made here that the differences obtained are of statistical nature and may or may not be significant in an engineering sense.

Each regression analysis in this report uses the linear model $Y = a + bX$. Each point (x) on a regression plot represents a data mean at its particular age at test. Variance about each regression line was used to compute a tolerance interval such that at 90% confidence 90% of the sample distribution will fall within this interval. This tolerance interval is extrapolated 24 months beyond the age of the last test data. The 't' value and the significance of this statistic, which are reported for each regression model, give an indication of the statistical significance of the slope of the trend line as compared to a line of zero slope.

## TEST RESULTS

A. VERY LOW RATE TENSILE (0.002 in/min):

Very low rate regressions for maximum stress, strain at maximum stress, strain at rupture and modulus show no significant change (figures 1, 5, 7, and 9). The stress at rupture regression shows a statistically significant increase (figure 3). The respective LGM-30 F & G regressions are shown for visual comparisons (figures 2, 4, 6, 8 and 10).

For the statistical comparison between acrylic acid and the respective TP-H1011 regression, variance is compared for all parameters. The comparison for slope and intercept can be made only on the parameters where variance is not statistically significant (Table 2).

For variance, only stress at rupture is not statistically different. The slopes are not statistically different with the intercept showing statistical differences (Table 2).

B. LOW RATE TENSILE (2.0 in/min):

The maximum stress regression shows no significant change and the stress at rupture shows a statistically significant increase (figures 11 and 13). The strains and modulus regressions do not show a significant change (figures 15, 17 and 19). The respective LGM-30 F & G regressions are show for a visual comparison (figures 12, 14, 16, 18 and 20).

For the statistical comparison of acrylic acid and TP-H1011 regressions, all parameters show a statistically significant difference (Table 2).

As illustrated in the regression for modulus (figure 19), all of the test data is well above the minimum requirement of 550 psi at 2.0 in/min and 77$^{o}$F.

C. HIGH RATE HYDROSTATIC TENSILE (1750 in/min, 800 psi):

The stresses and modulus show a statistically significant increase (figures 21, 23, and 29). The strains show a statistically significant decrease (figures 25 and 27). F & G regressions (figures 22, 24, 26, 28 and 30) are included for visual comparison with the respective Acrylic Acid regressions.

For the statistical comparison between the acrylic acid and TP-H1011 only the strain at maximum stress variance is statistically comparable. The slope and intercept for strain at maximum stress show a statistically significant difference (Table 2).

D. CONSTANT STRAIN:

The constant strain at rupture regression shows a statistically significant decrease (figure 31). The F & G regression (figure 32) is included for a visual comparison.

A comparison of the variance with the respective F & G slope shows a statistically significant difference (Table 2).

E. TEAR ENERGY:

Tear energy does not show a significant change (figure 33) with the time to tear showing a statistically significant increase (figure 35). F & G regressions (figures 34 and 36) are included for visual comparison with the respective acrylic acid regressions.

Comparison of the slopes with the respective F & G slopes show that the cohesive energy is not significantly different while the variance for time to tear is significantly different (Table 2).

## CONCLUSIONS

The propellant data from the special acrylic acid testing shows a gradual change. From the analysis of the data, the propellant shows a small increase in stress with aging and the strain is gradually decreasing with age.

These trends are similar to the propellant produced from the monomer previously used.

The modulus is well above the Thiokol requirement of at least 5! psi modulus at 2.0 in/min and 77°F test conditions. The modulus is ; ) increasing with age.

Based on this analysis, it is concluded that the propellant produced with glacial acrylic acid polymer is performing and aging satisfactorily.

TABLE 1

TEST PROGRAM

Half gallon cartons of propellant were cast from the same mixes that went into the full scale motors. These were cast and labelled for the respective motors and from these cartons, specimens were cut for the tests and conditions listed below:

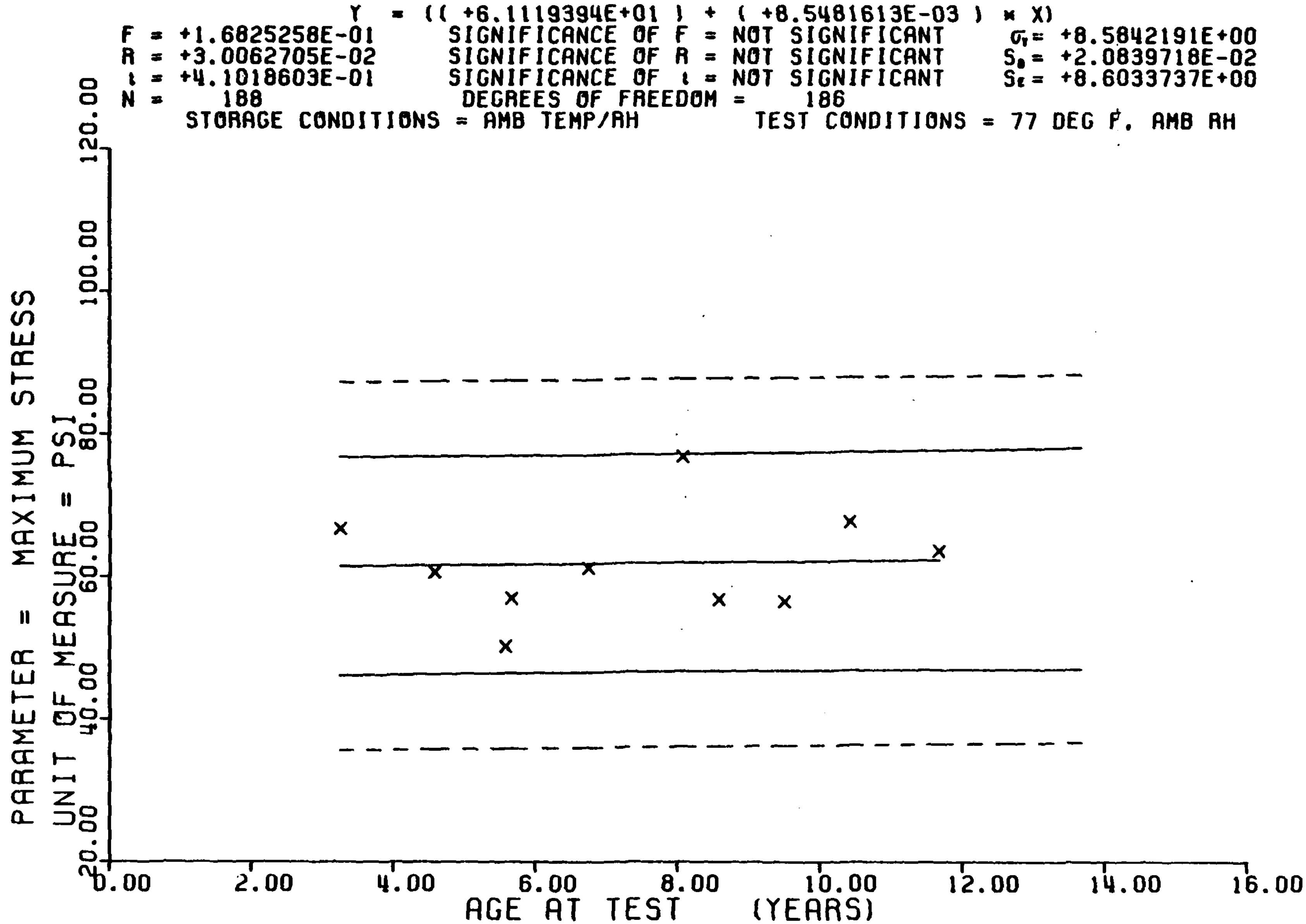
| Test | Condition | Configuration | Per Cond |
|---|---|---|---|
| Low Rate Tensile | 2.0 in/min | 1/2" JANNAF Dog Bone | 12 |
| Very Low Rate Tensile | 2 x $10^{-3}$ in/min | 1/2" JANNAF Dog Bone | 12 |
| Constant Strain | | JANNAF Dog Bone | 12 |
| Hydrostatic High Rate Tensile | 800 psig, 1750 in/min | 3/4" GL Dog Bone | 12 |
| Tear Energy | 77°F ± 2° | 0.10" x 1.18" x 3" | 12 |

TABLE 2

ANALYSIS OF COVARIANCE COMPARISON OF REGRESSIONS
ACRYLIC ACID vs TP-H1011 CARTON PROPELLANT

| Test | Variance | Slope | Intercept |
|---|---|---|---|
| Tensile at 0.002 in/min: | | | |
| Maximum Stress | S | | |
| Stress at Rupture | NS | NS | S |
| Strain at Maximum Stress | S | | |
| Strain at Rupture | S | | |
| Modulus | S | | |
| Tensile at 2.0 in/min: | | | |
| Maximum Stress | S | | |
| Stress at Rupture | S | | |
| Strain at Maximum Stress | S | | |
| Strain at Rupture | S | | |
| Modulus | S | | |
| Hydrostatic Tensile at 1750 in/min: | | | |
| Maximum Stress | S | | |
| Stress at Rupture | S | | |
| Strain at Maximum Stress | NS | S | S |
| Strain at Rupture | S | | |
| Modulus | S | | |
| Constant Strain: | | | |
| Strain at Rupture | S | | |
| Tear Energy: | | | |
| Cohesive Energy | NS | NS | NS |
| Time to Tear | S | | |

S = Significantly Different
NS = Not Significantly Different




TENSILE, MAXIMUM STRESS AT 0.002 IN/MIN, ACRYLIC ACID STUDY

Figure 1

Y = (( +7.6081806E+01 ) + ( +4.9566603E-02 ) * X)

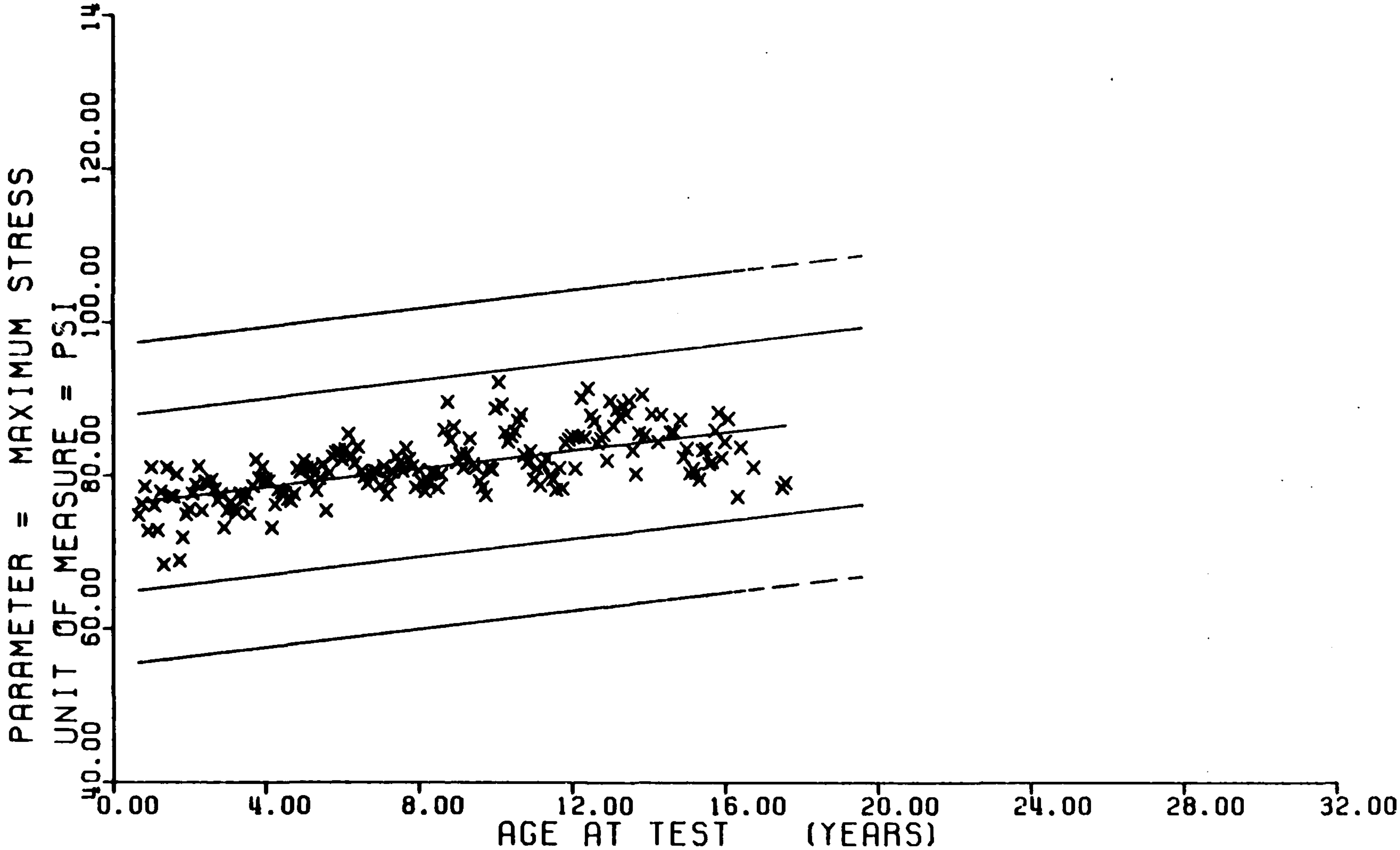
F = +1.6364286E+03 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_Y$ = +7.2494482E+00

R = +2.7306535E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_B$ = +1.2252949E-03

$\iota$ = +4.0452794E+01 SIGNIFICANCE OF $\iota$ = SIGNIFICANT $S_E$ = +6.9741081E+00

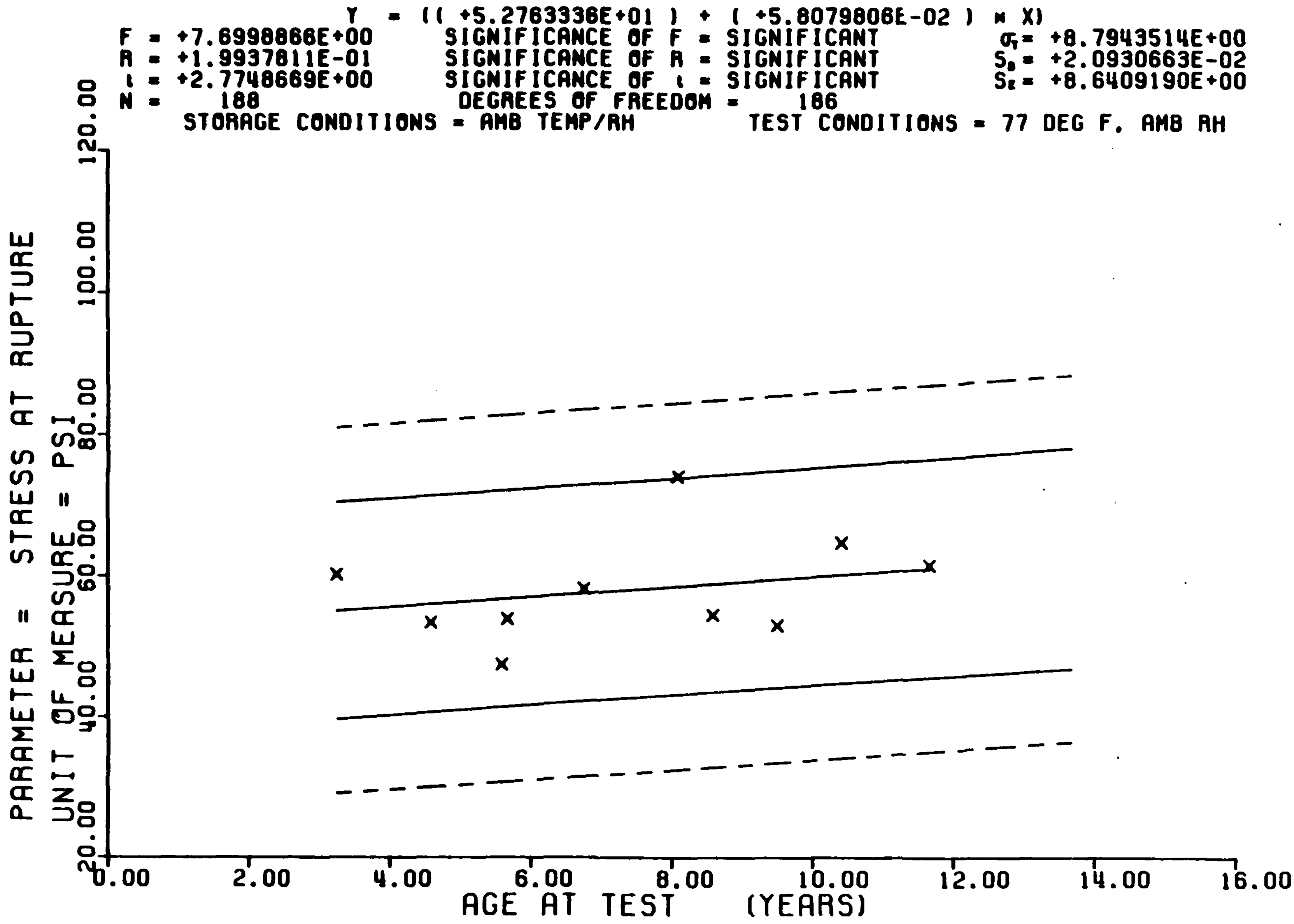
N = 20312 DEGREES OF FREEDOM = 20310

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH



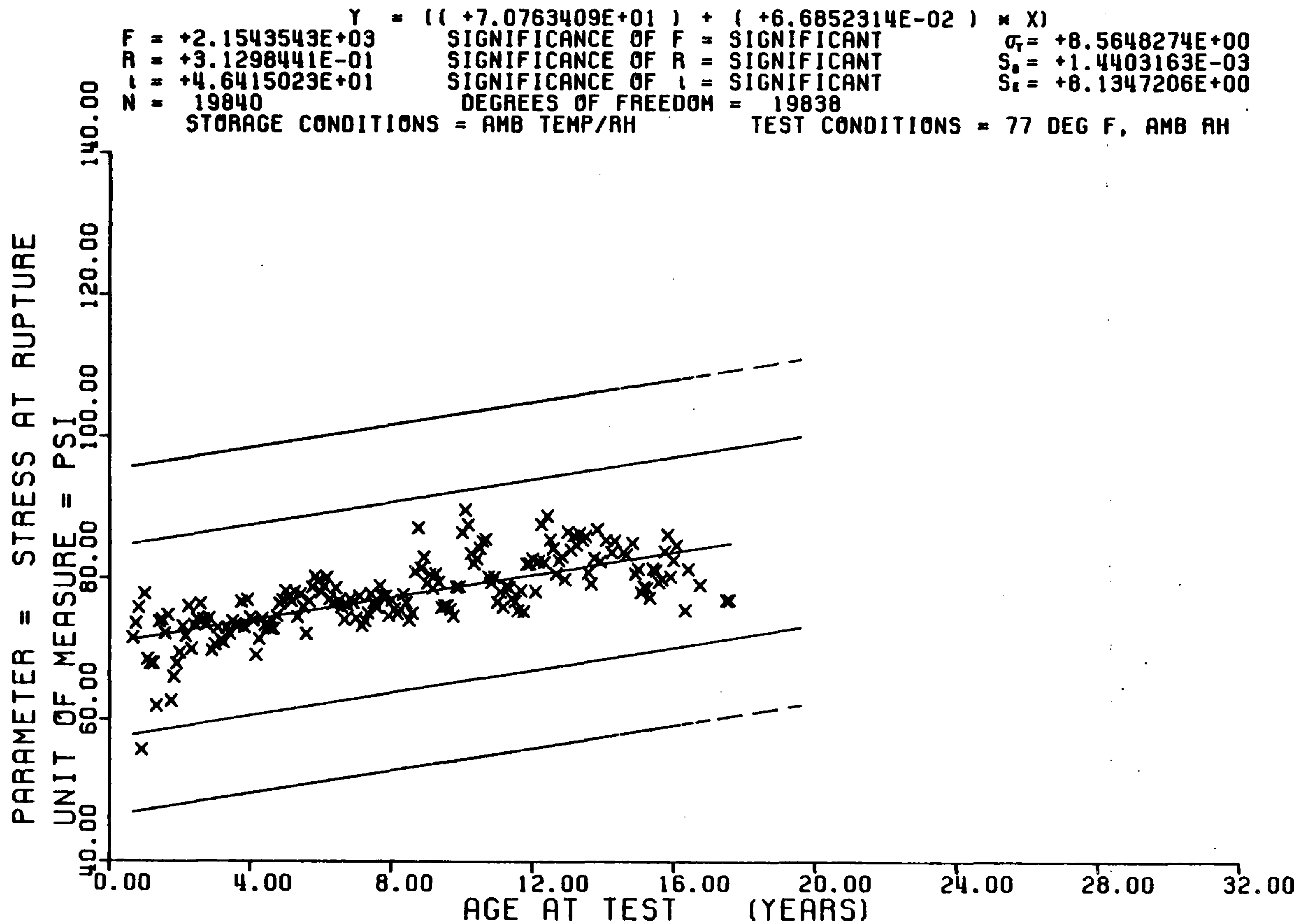

TENSILE, MAXIMUM STRESS, WING 6 TPH-1011 PROPELLANT AT 0.002 IN/MIN

Figure 2




TENSILE, STRESS AT RUPTURE, 0.002 IN/MIN, ACRYLIC ACID STUDY

Figure 3




TENSILE, STRESS AT RUPTURE, WING 6 TPH-1011 PROPELLANT AT 0.002 IN/MIN

Figure 4

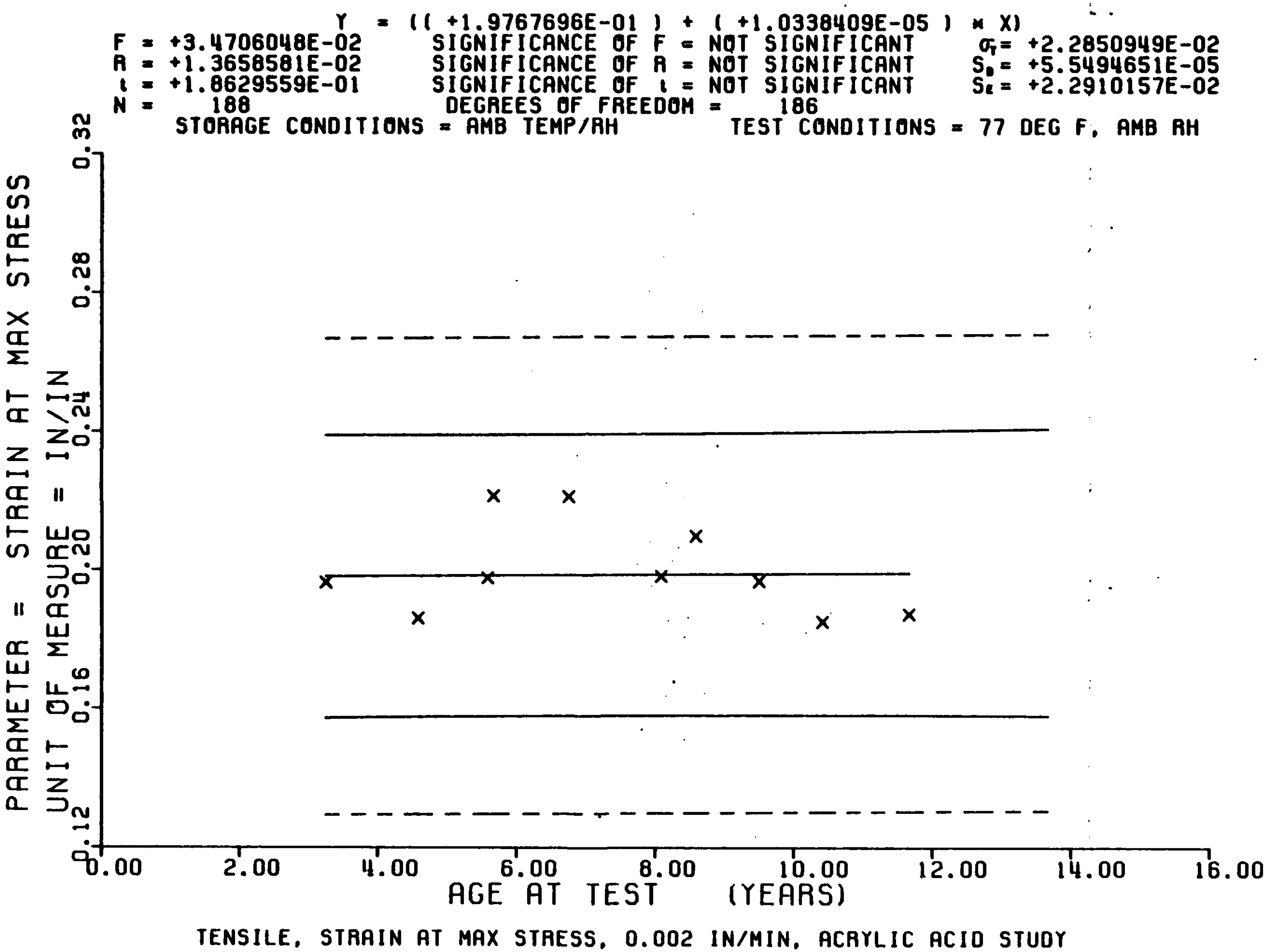

Y = (( +1.9767696E-01 ) + ( +1.0338409E-05 ) * X)
F = +3.4706048E-02 SIGNIFICANCE OF F = NOT SIGNIFICANT $\sigma_Y$ = +2.2850949E-02
R = +1.3658581E-02 SIGNIFICANCE OF R = NOT SIGNIFICANT $S_b$ = +5.5494651E-05
t = +1.8629559E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT $S_t$ = +2.2910157E-02
N = 188 DEGREES OF FREEDOM = 186
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH
PARAMETER = STRAIN AT MAX STRESS
UNIT OF MEASURE = IN/IN
0.12
0.16
0.20
0.24
0.28
0.32
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AGE AT TEST (YEARS)
TENSILE, STRAIN AT MAX STRESS, 0.002 IN/MIN, ACRYLIC ACID STUDY

Figure 5

Y = (( +2.0674716E-01 ) + ( -2.2020903E-05 ) * X)

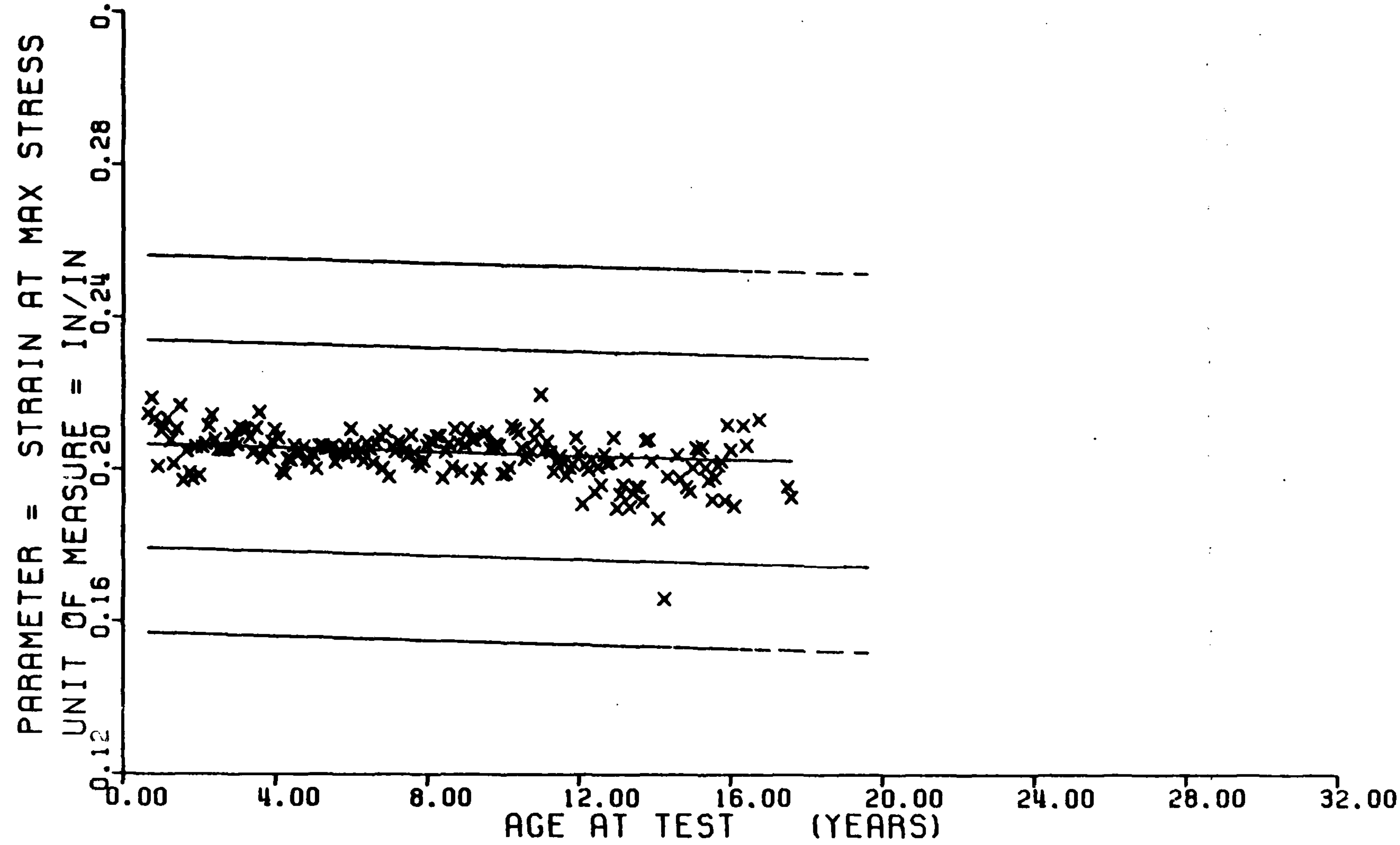
F = +5.7540462E+01 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_Y$ = +1.6545995E-02

R = -5.3153031E-02 SIGNIFICANCE OF R = SIGNIFICANT $S_B$ = +2.9030094E-06

t = +7.5855430E+00 SIGNIFICANCE OF t = SIGNIFICANT $S_E$ = +1.6523012E-02

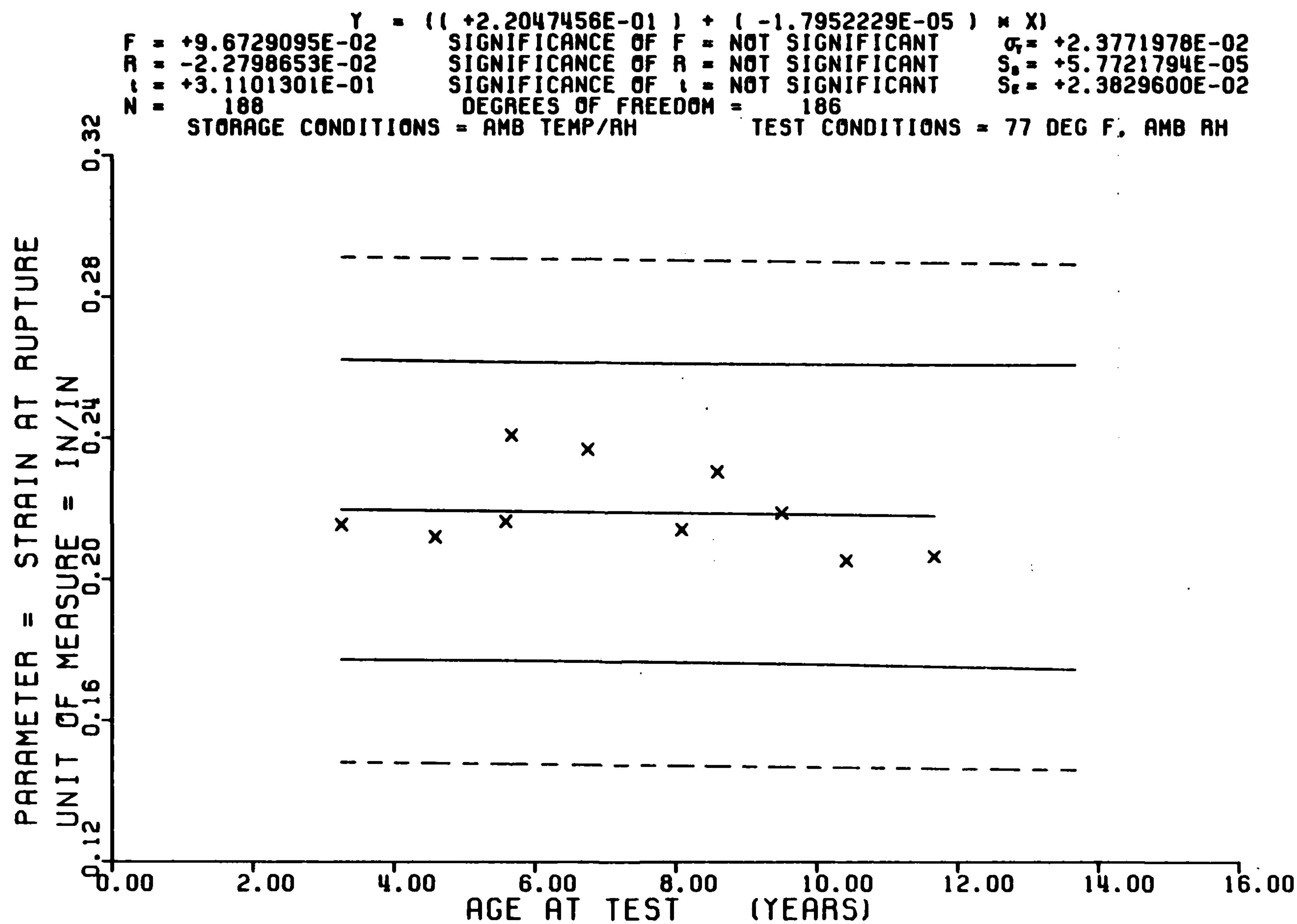
N = 20311 DEGREES OF FREEDOM = 20309

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH




TENSILE, STRAIN AT MAXIMUM STRESS, WING 6 TPH-1011 PROPELLANT AT 0.002 IN/MIN

Figure 6

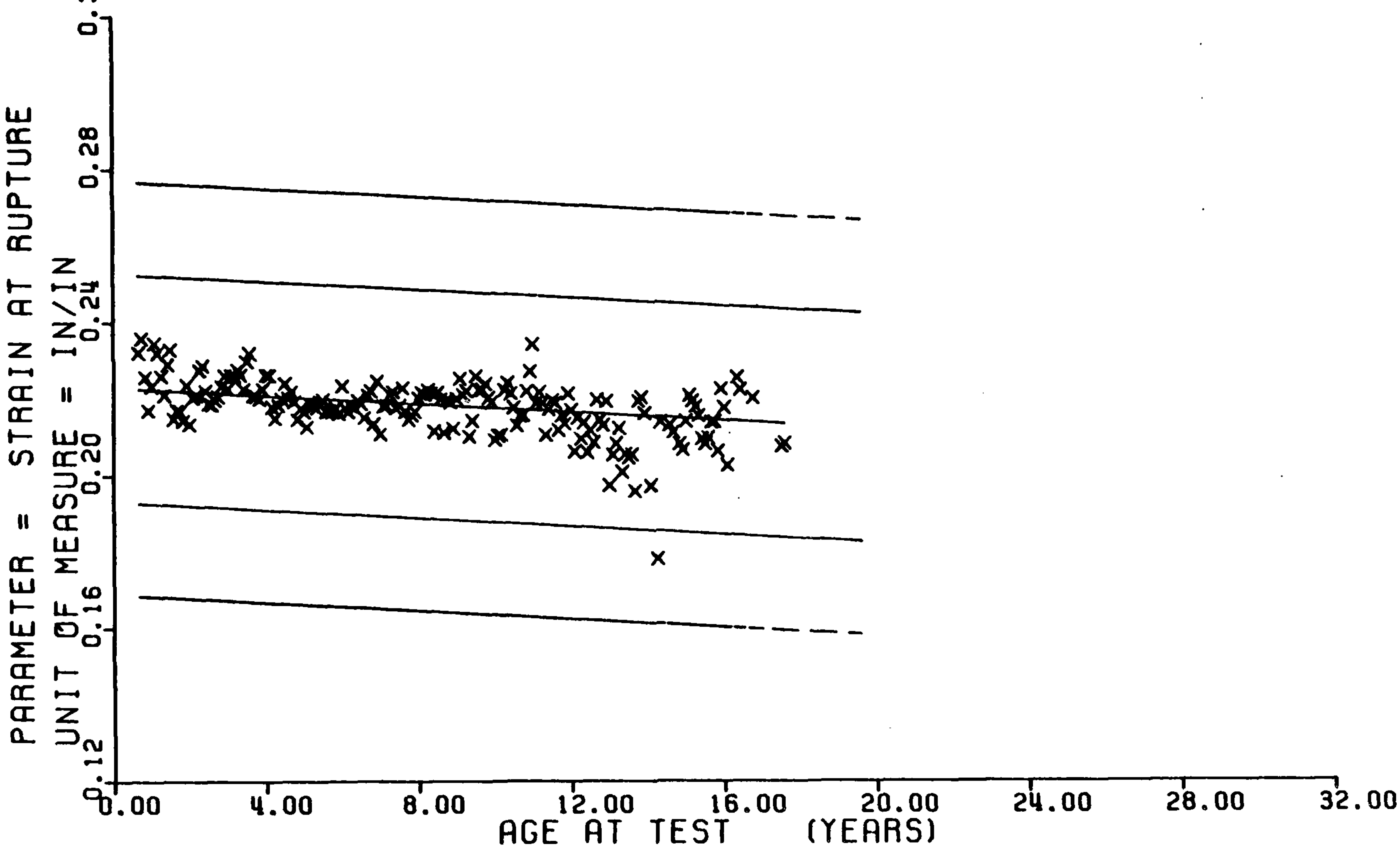



TENSILE, STRAIN AT RUPTURE, 0.002 IN/MIN, ACRYLIC ACID STUDY

Figure 7

Y = (( +2.2294814E-01 ) + ( -4.5272074E-05 ) * X)

F = +2.0450403E+02    SIGNIFICANCE OF F = SIGNIFICANT    $\sigma_Y$ = +1.8108856E-02
R = -9.9843646E-02    SIGNIFICANCE OF R = SIGNIFICANT    $S_b$ = +3.1657706E-06
t = +1.4300490E+01    SIGNIFICANCE OF t = SIGNIFICANT    $S_E$ = +1.8018812E-02
N = 20312    DEGREES OF FREEDOM = 20310
STORAGE CONDITIONS = AMB TEMP/RH    TEST CONDITIONS = 77 DEG F, AMB RH




TENSILE, STRAIN AT RUPTURE, WING 6 TPH-1011 PROPELLANT AT 0.002 IN/MIN

Figure 8

Y = (( +4.3563701E+02 ) + ( +5.4595272E-03 ) * X)

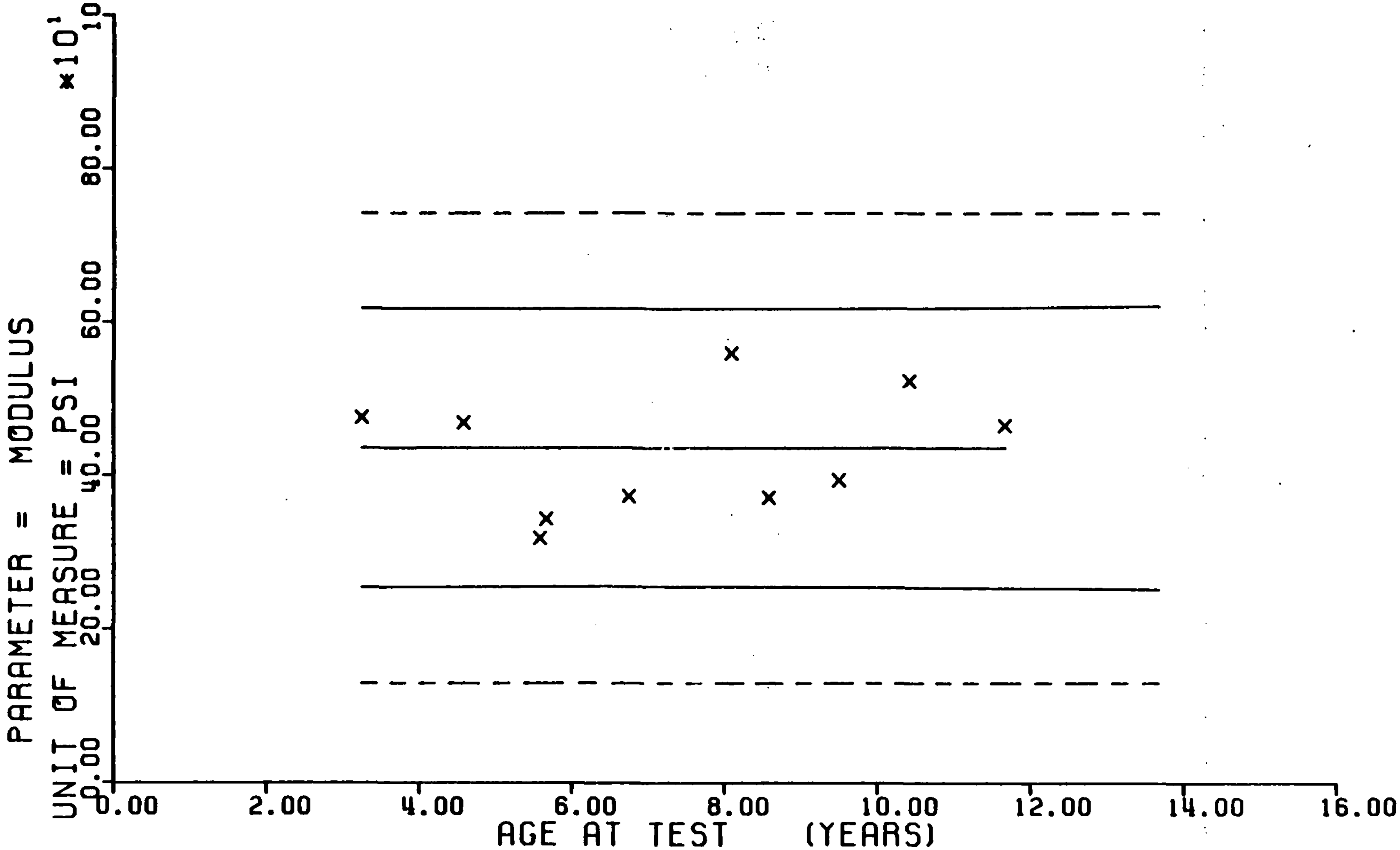
F = +4.8754371E-04 SIGNIFICANCE OF F = NOT SIGNIFICANT $\sigma_Y$ = +1.0180320E+02

R = +1.6190107E-03 SIGNIFICANCE OF R = NOT SIGNIFICANT $S_B$ = +2.4725680E-01

t = +2.2080392E-02 SIGNIFICANCE OF t = NOT SIGNIFICANT $S_E$ = +1.0207636E+02

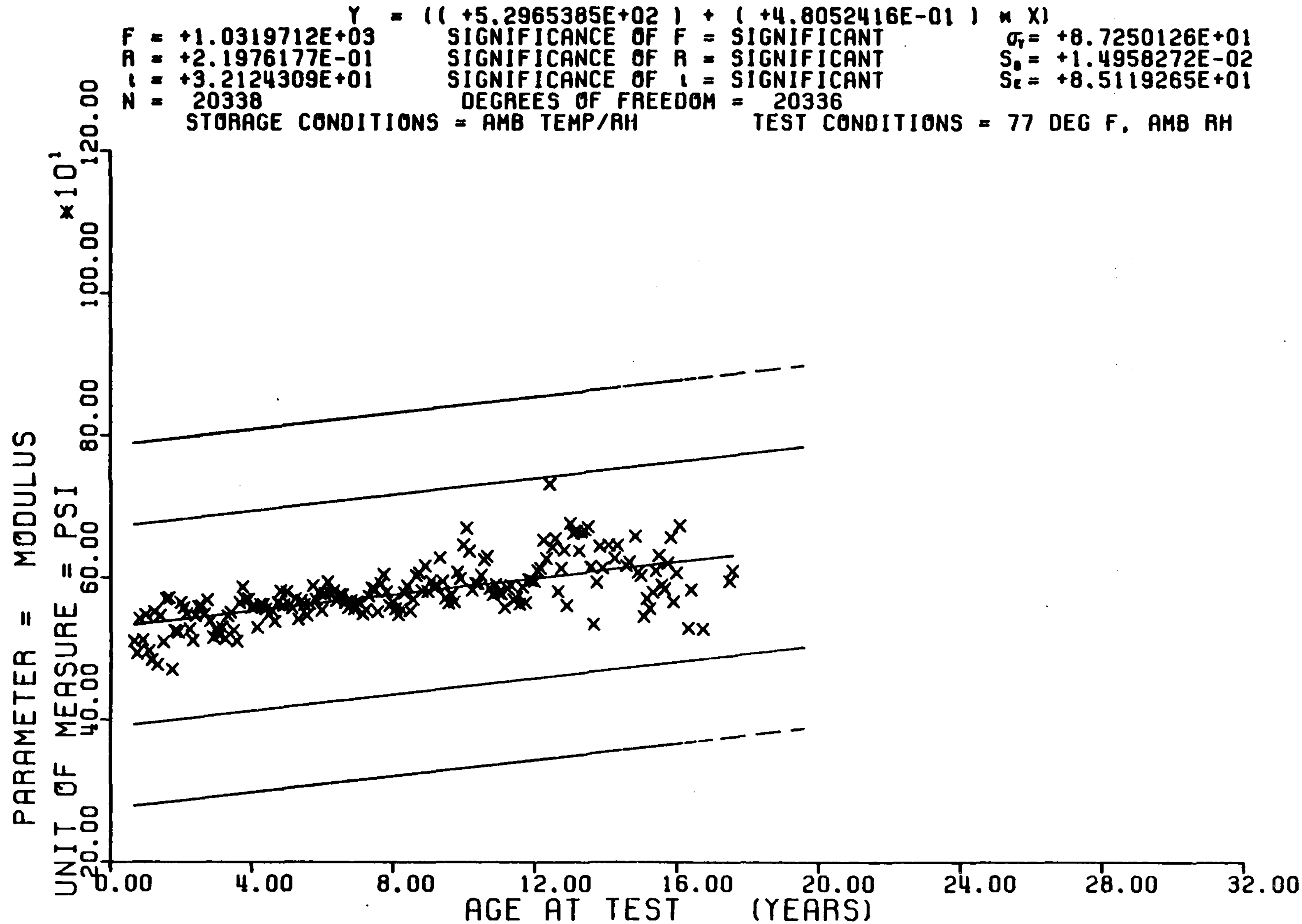
N = 188 DEGREES OF FREEDOM = 186

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH



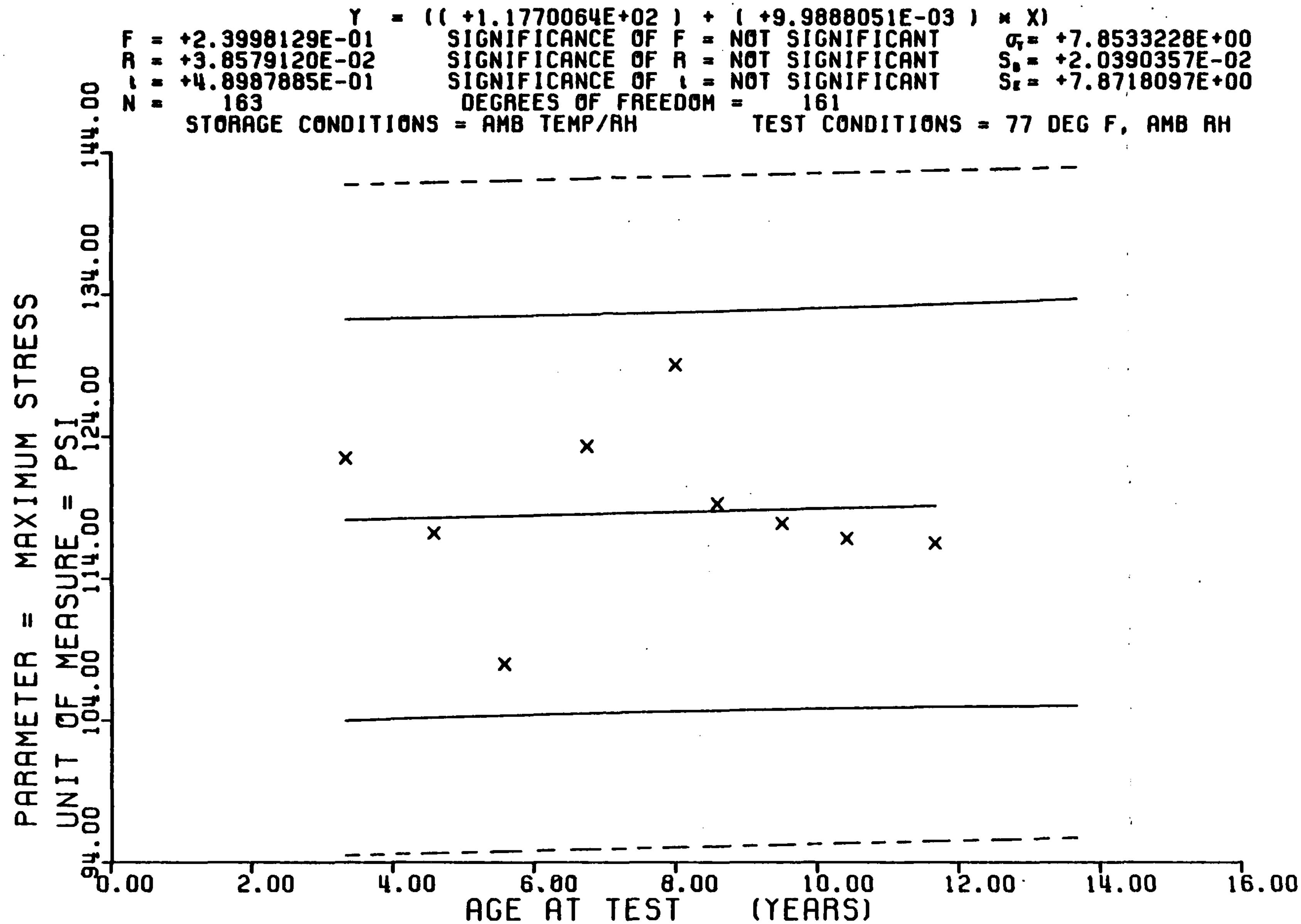

TENSILE, MODULUS AT 0.002 IN/MIN, ACRYLIC ACID STUDY

Figure 9




TENSILE, MODULUS, WING 6 TPH-1011 PROPELLANT AT 0.002 IN/MIN

Figure 10




TENSILE, MAXIMUM STRESS AT 2 IN/MIN, ACRYLIC ACID STUDY

Figure 11

$Y = ((+1.2970804E+02) + (+4.5879069E-02) * X)$

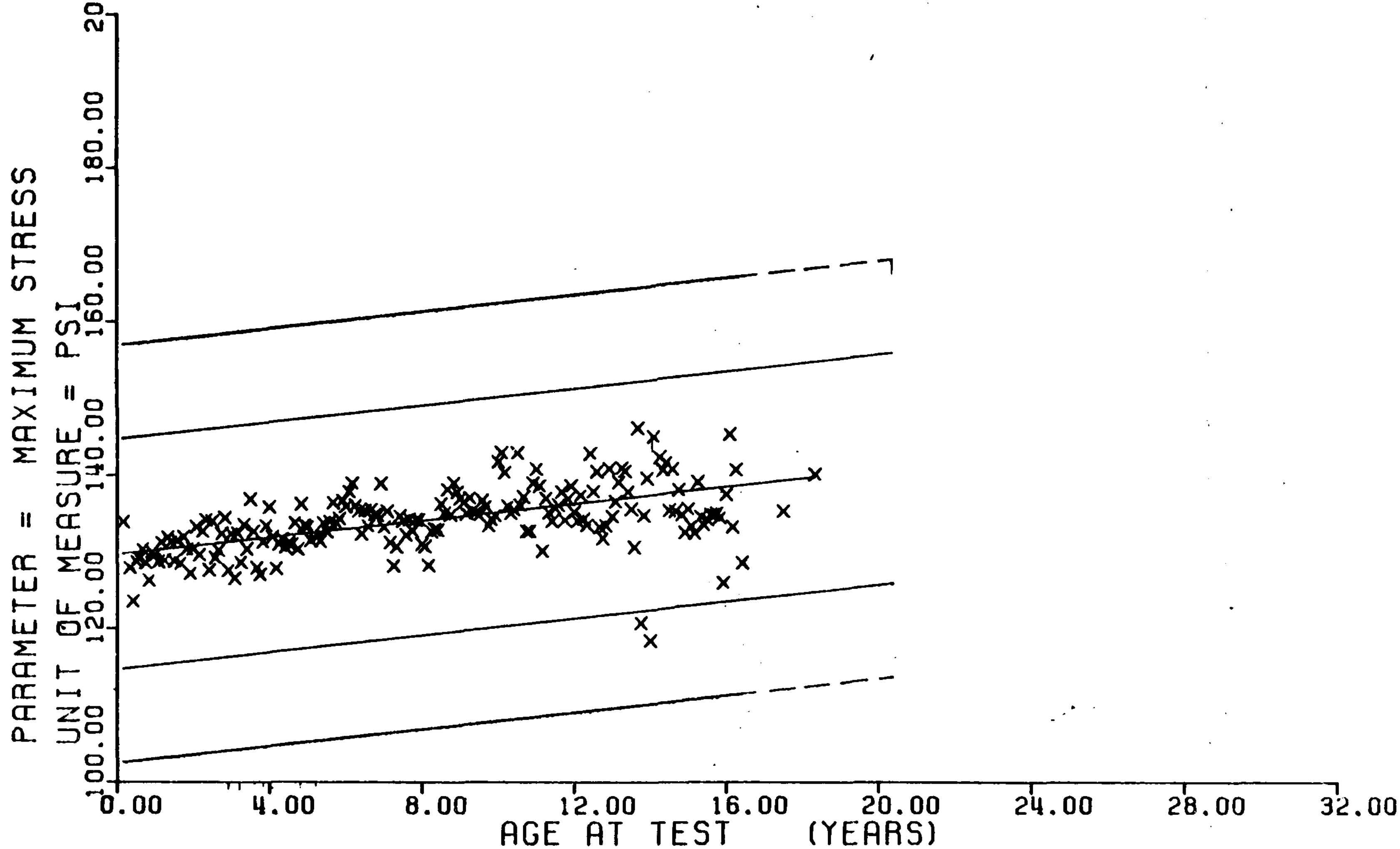
F = +1.0070152E+03 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_T$ = +9.3217316E+00

R = +2.2825124E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_a$ = +1.4457612E-03

$t$ = +3.1733502E+01 SIGNIFICANCE OF $t$ = SIGNIFICANT $S_\varepsilon$ = +9.0759067E+00

N = 18324 DEGREES OF FREEDOM = 18322

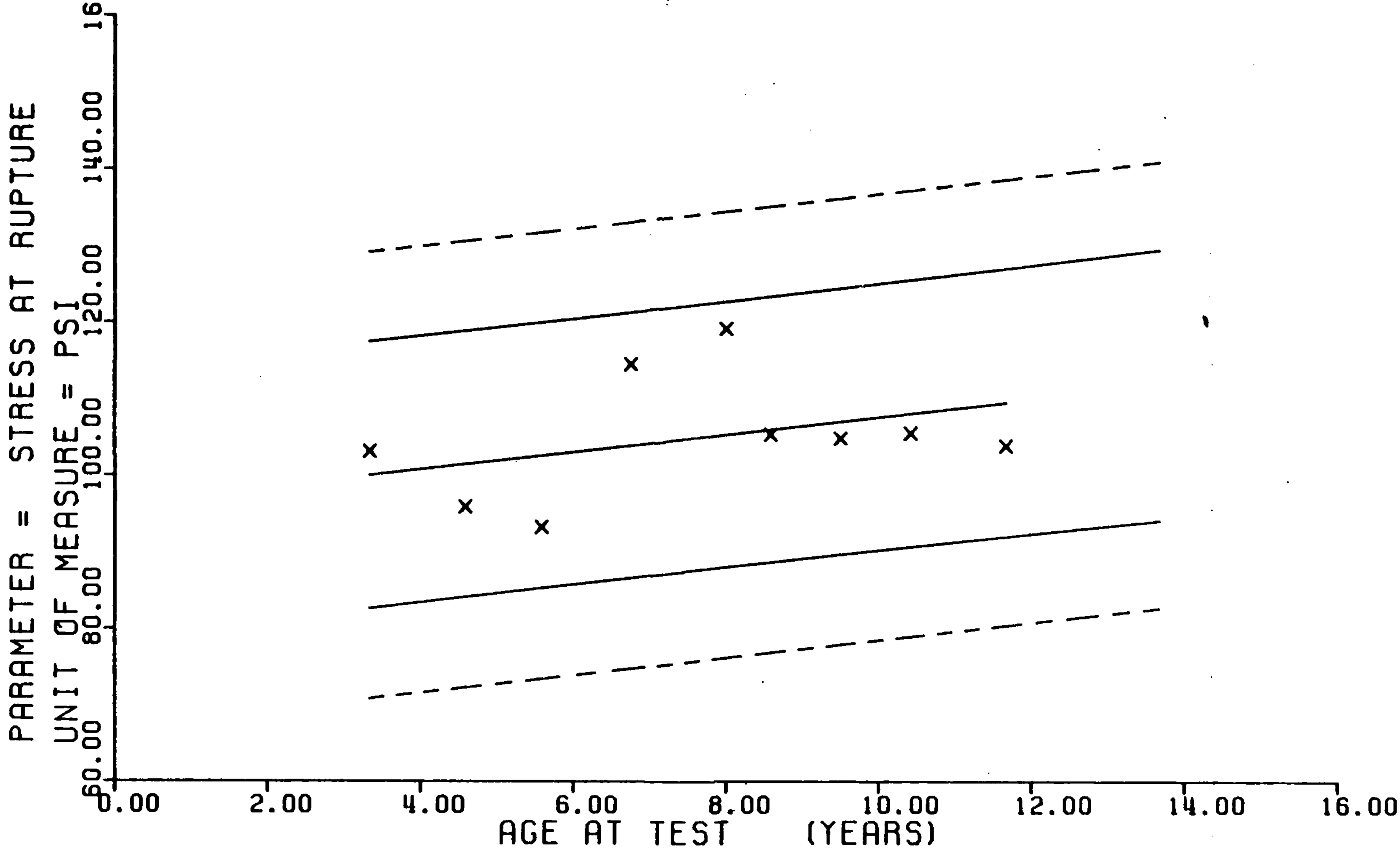
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH




TENSILE, MAXIMUM STRESS, WING 6 TPH-1011 PROPELLANT AT 2 IN/MIN

Figure 12

Y = (( +9.6211471E+01 ) + ( +9.4261913E-02 ) * X)
F = +1.4065332E+01 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_T$ = +1.0086803E+01
R = +2.8344899E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_B$ = +2.5133979E-02
t = +3.7503776E+00 SIGNIFICANCE OF t = SIGNIFICANT $S_E$ = +9.7031108E+00
N = 163 DEGREES OF FREEDOM = 161
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH



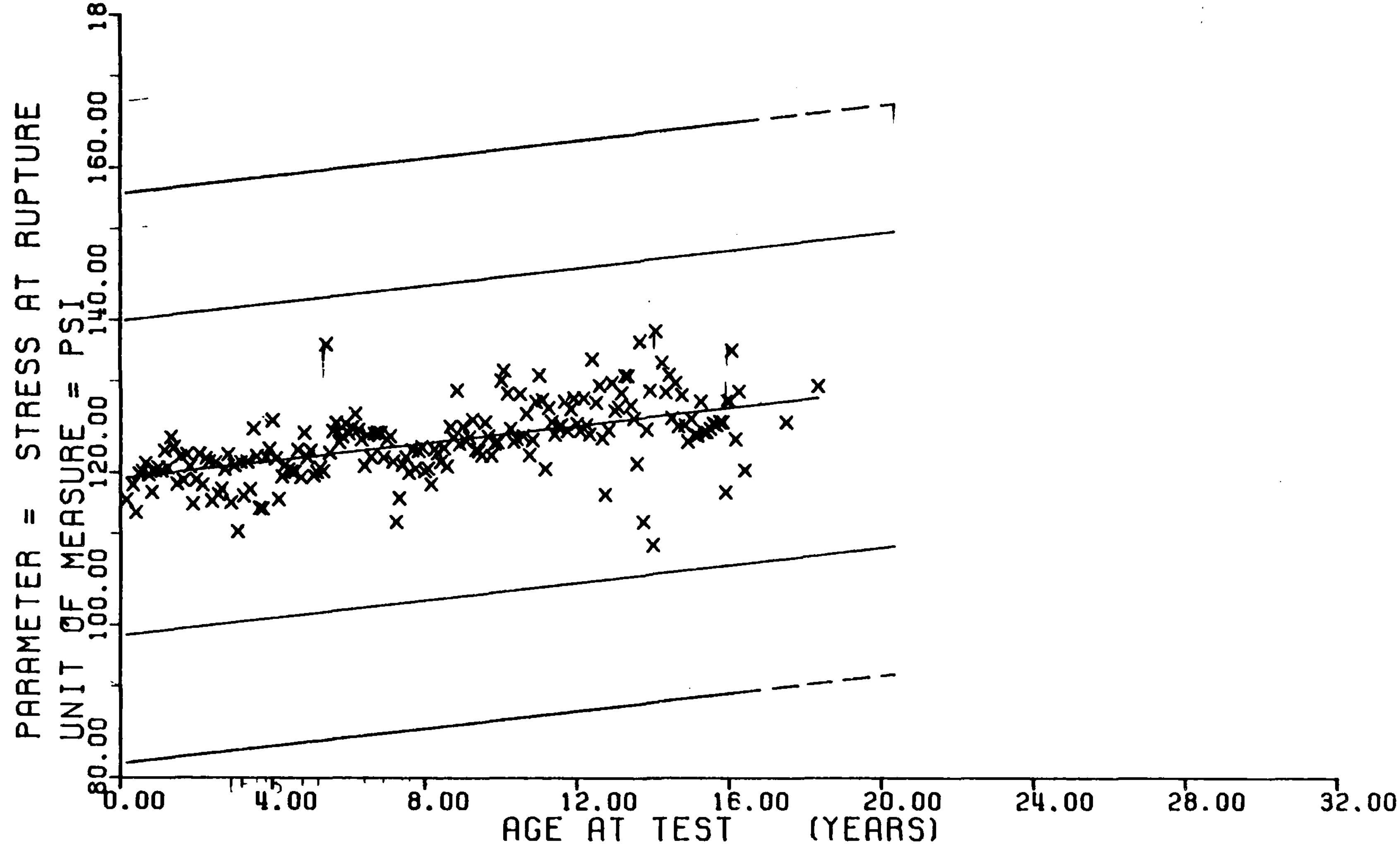

TENSILE, STRESS AT RUPTURE, 2 IN/MIN, ACRYLIC ACID STUDY

Figure 13

Y = (( +1.1925965E+02 ) + ( +4.8230779E-02 ) * X)

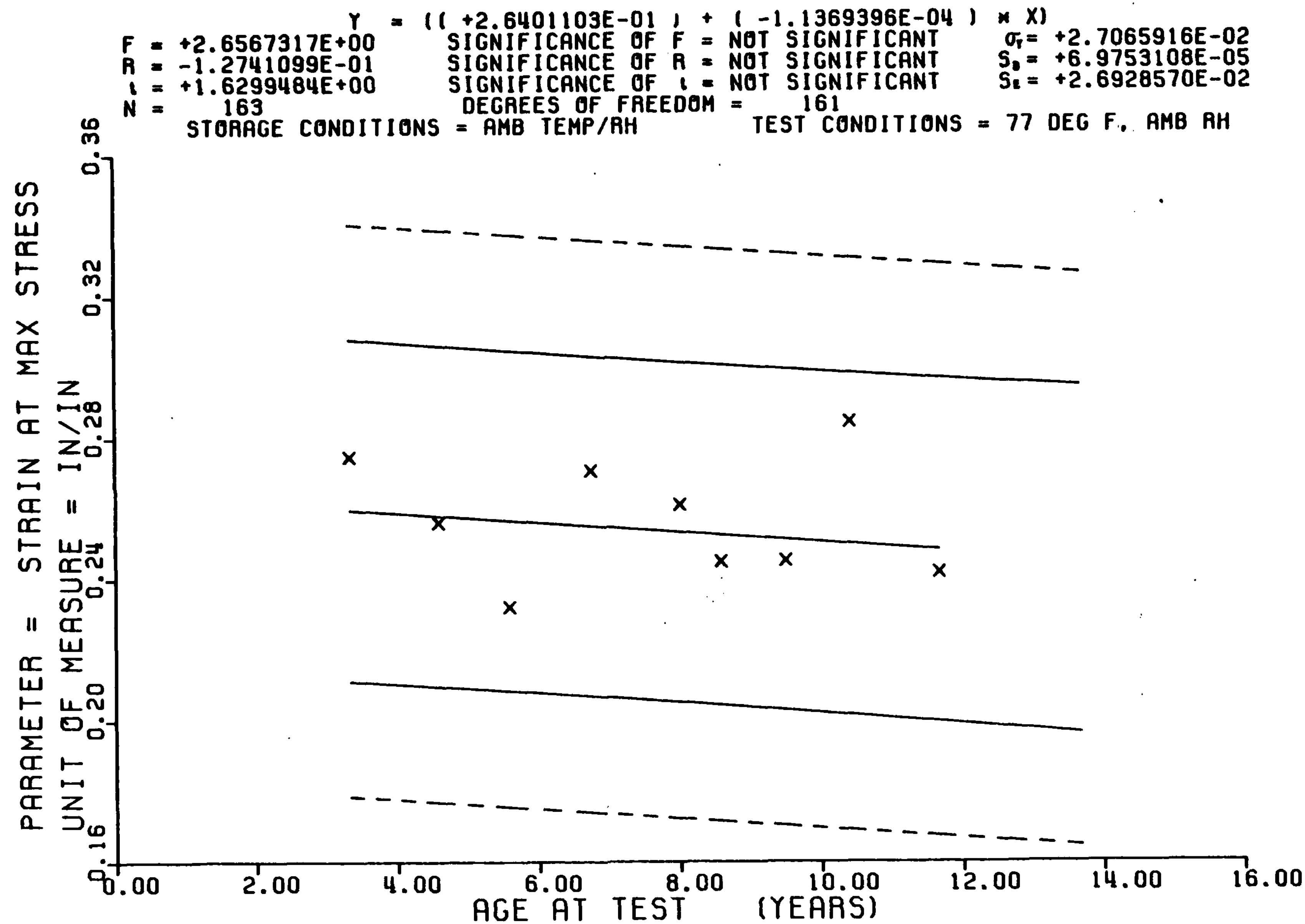
F = +5.9019725E+02  SIGNIFICANCE OF F = SIGNIFICANT  $\sigma_Y$ = +1.2659894E+01
R = +1.7667436E-01  SIGNIFICANCE OF R = SIGNIFICANT  $S_B$ = +1.9852979E-03
t = +2.4293975E+01  SIGNIFICANCE OF t = SIGNIFICANT  $S_E$ = +1.2461086E+01
N = 18320  DEGREES OF FREEDOM = 18318

STORAGE CONDITIONS = AMB TEMP/RH  TEST CONDITIONS = 77 DEG F, AMB RH



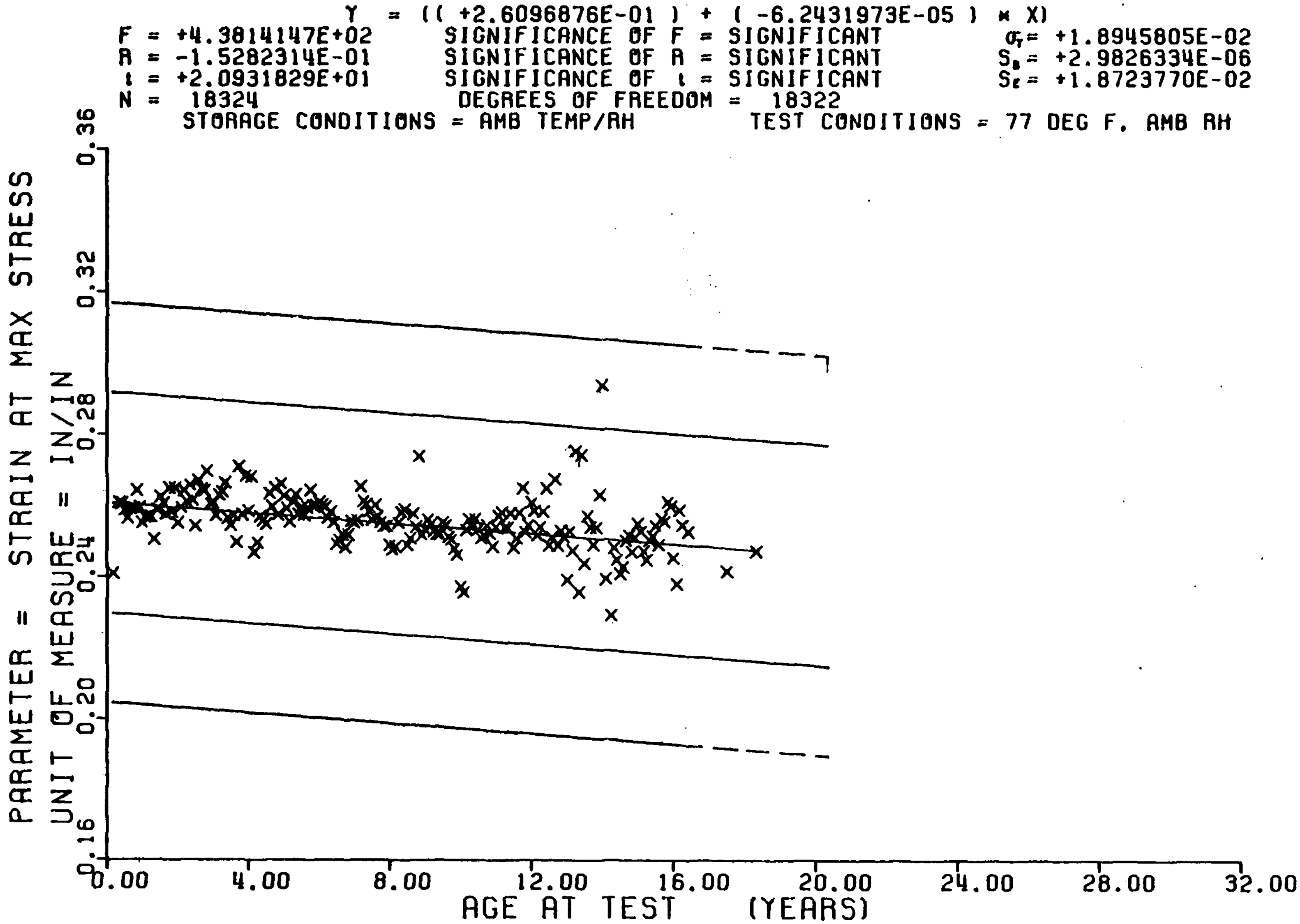

TENSILE, STRESS AT RUPTURE, WING 6 TPH-1011 PROPELLANT AT 2 IN/MIN

Figure 14



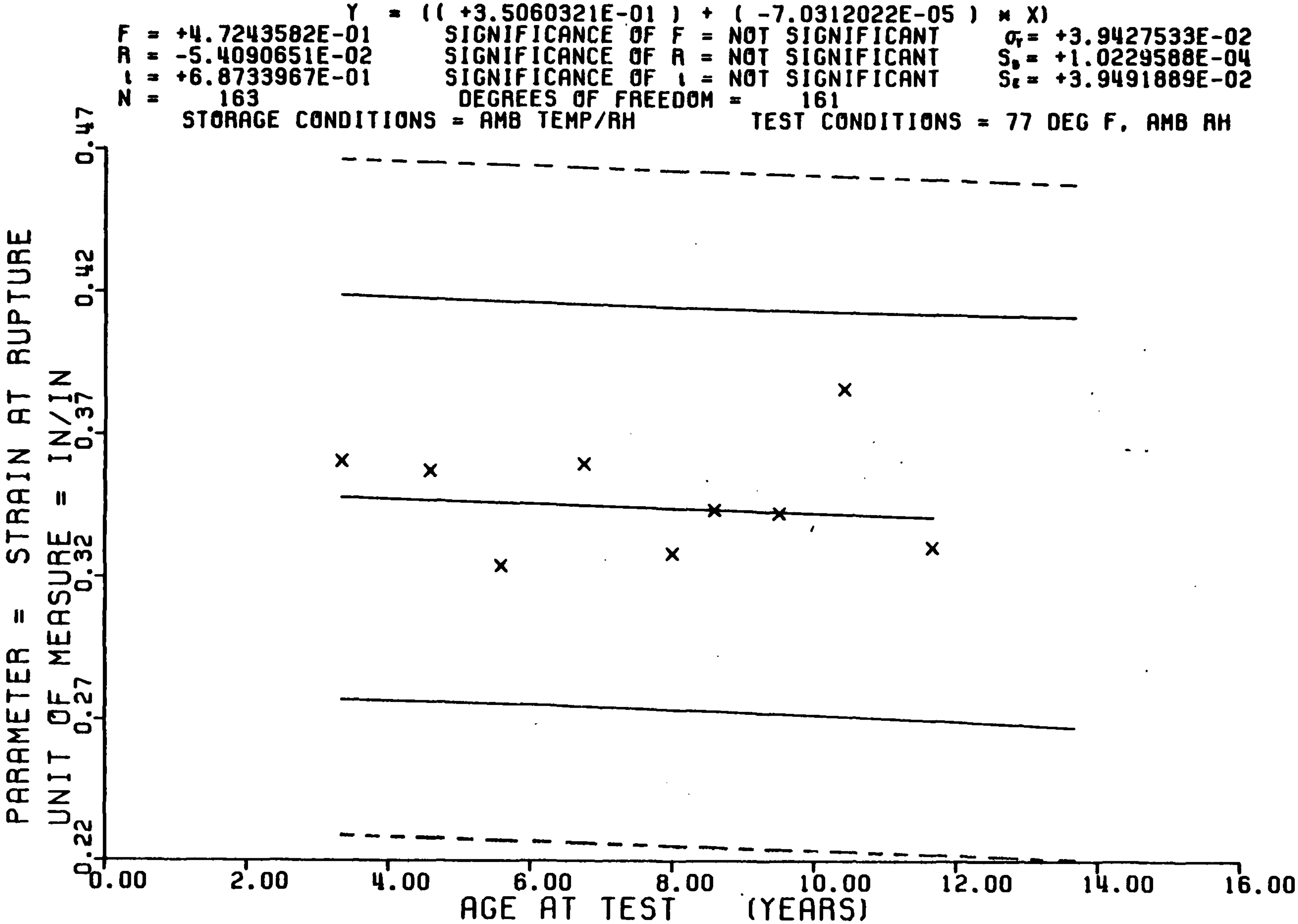

TENSILE, STRAIN AT MAX STRESS, 2 IN/MIN, ACRYLIC ACID STUDY

Figure 15



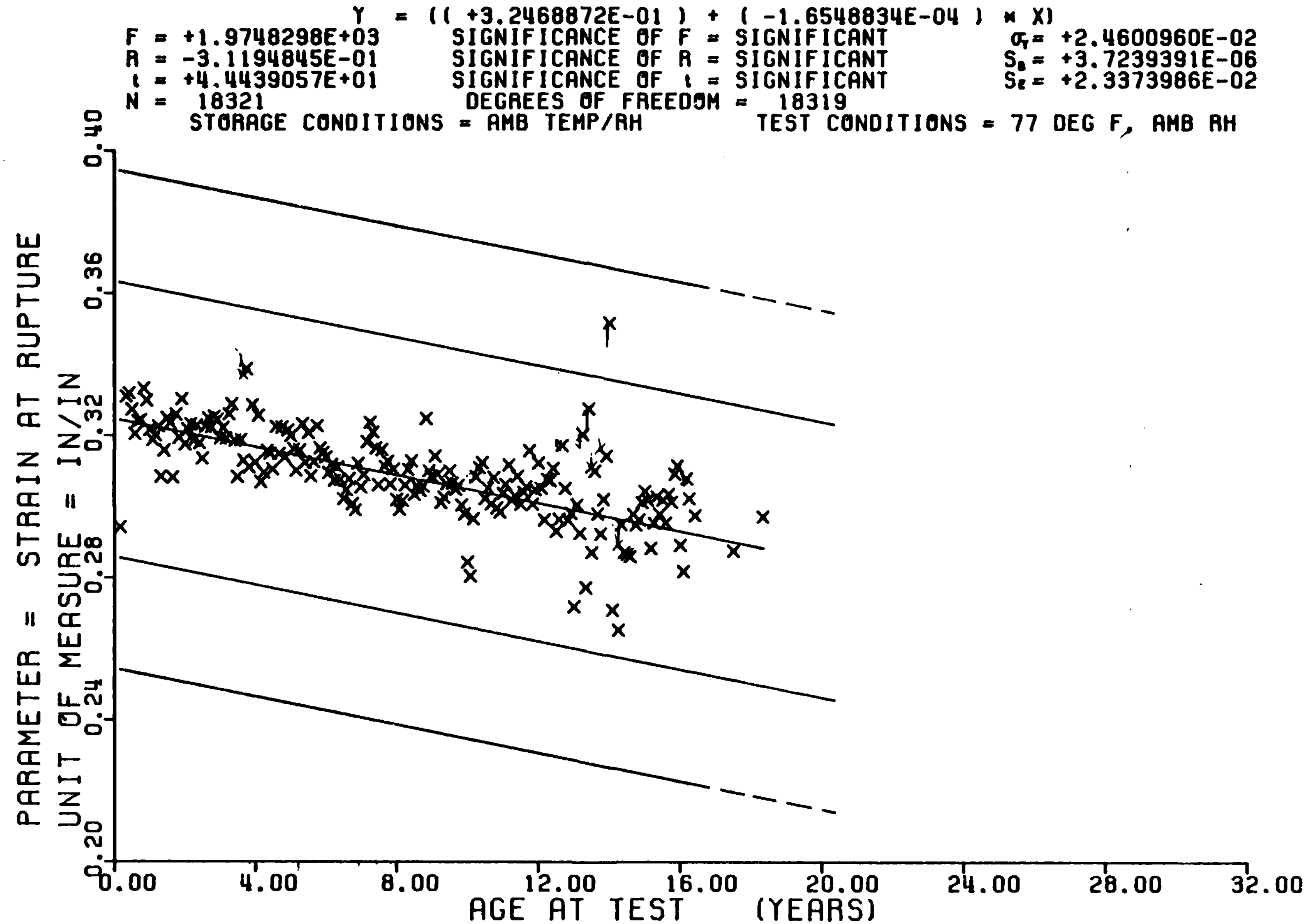

TENSILE, STRAIN AT MAXIMUM STRESS, WING 6 TPH-1011 PROPELLANT AT 2 IN/MIN

Figure 16



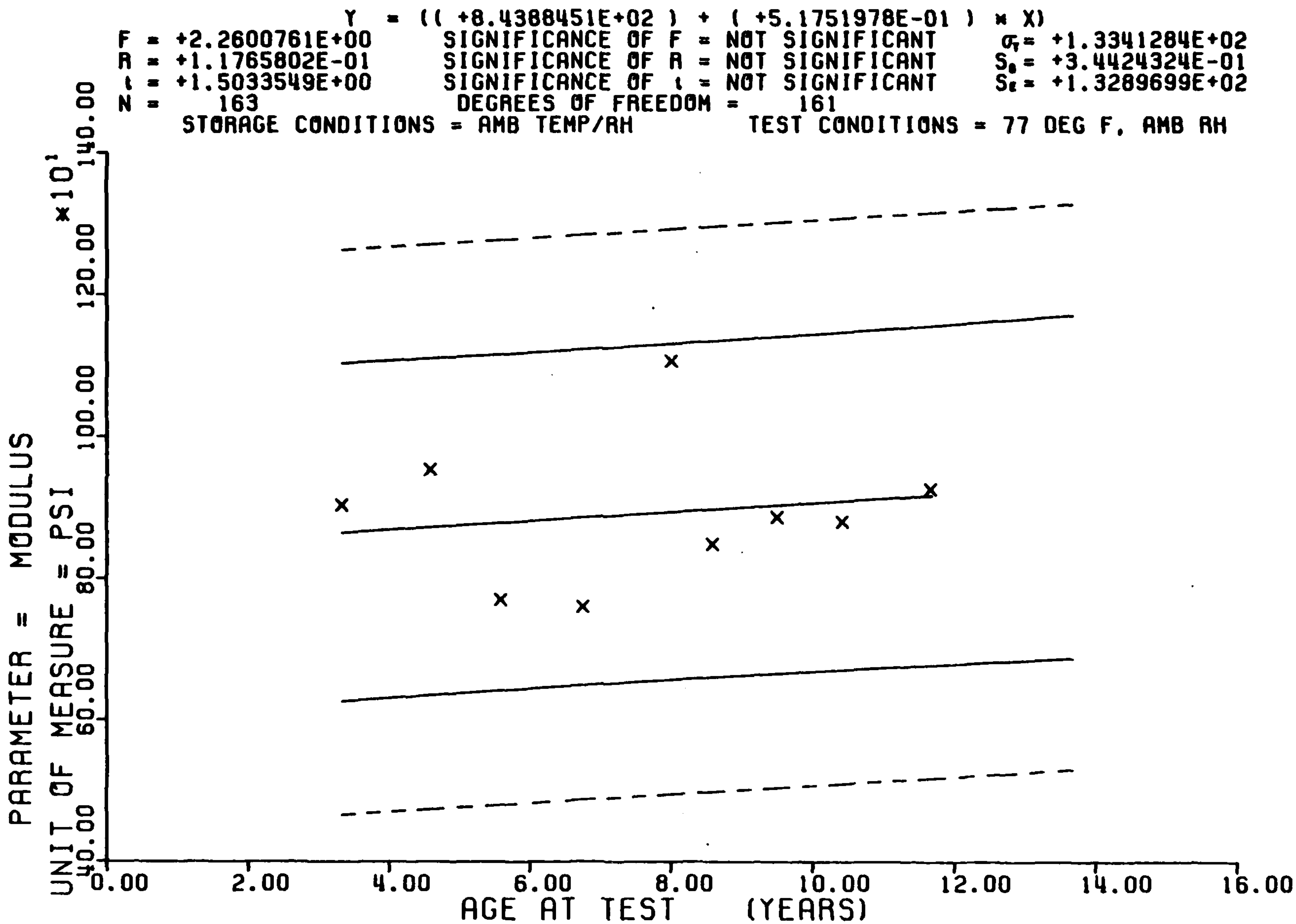

TENSILE, STRAIN AT RUPTURE, 2 IN/MIN, ACRYLIC ACID STUDY

Figure 17




TENSILE, STRAIN AT RUPTURE, WING 6 TPH-1011 PROPELLANT AT 2 IN/MIN

Figure 18




TENSILE, MODULUS AT 2 IN/MIN, ACRYLIC ACID STUDY

Figure 19

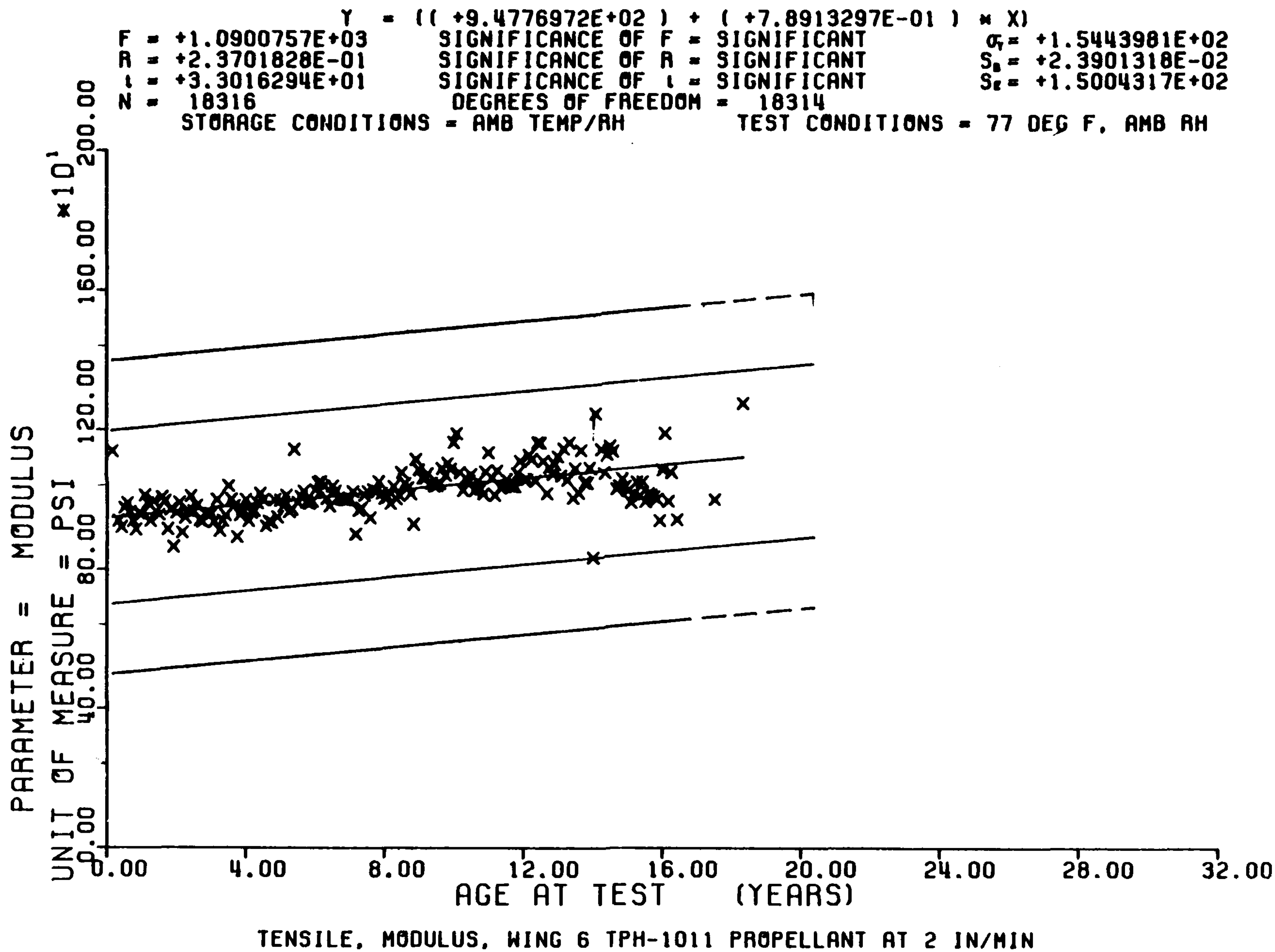

Y = (( +9.4776972E+02 ) + ( +7.8913297E-01 ) * X)
F = +1.0900757E+03 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_T$ = +1.5443981E+02
R = +2.3701828E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_B$ = +2.3901318E-02
t = +3.3016294E+01 SIGNIFICANCE OF t = SIGNIFICANT $S_E$ = +1.5004317E+02
N = 18316 DEGREES OF FREEDOM = 18314
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH
PARAMETER = MODULUS
UNIT OF MEASURE = PSI
*10[1]
0.00
40.00
80.00
120.00
160.00
200.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
TENSILE, MODULUS, WING 6 TPH-1011 PROPELLANT AT 2 IN/MIN

Figure 20

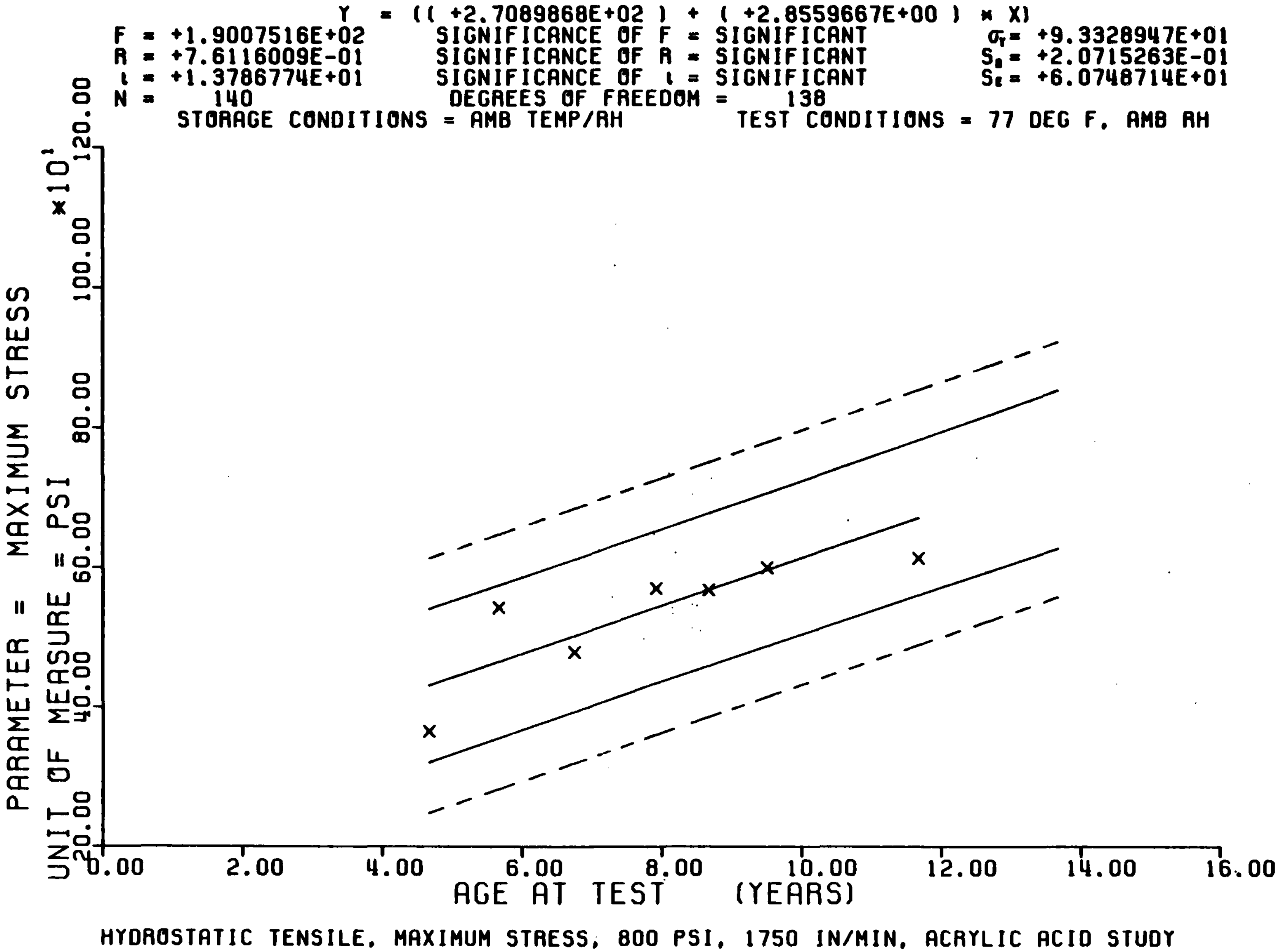
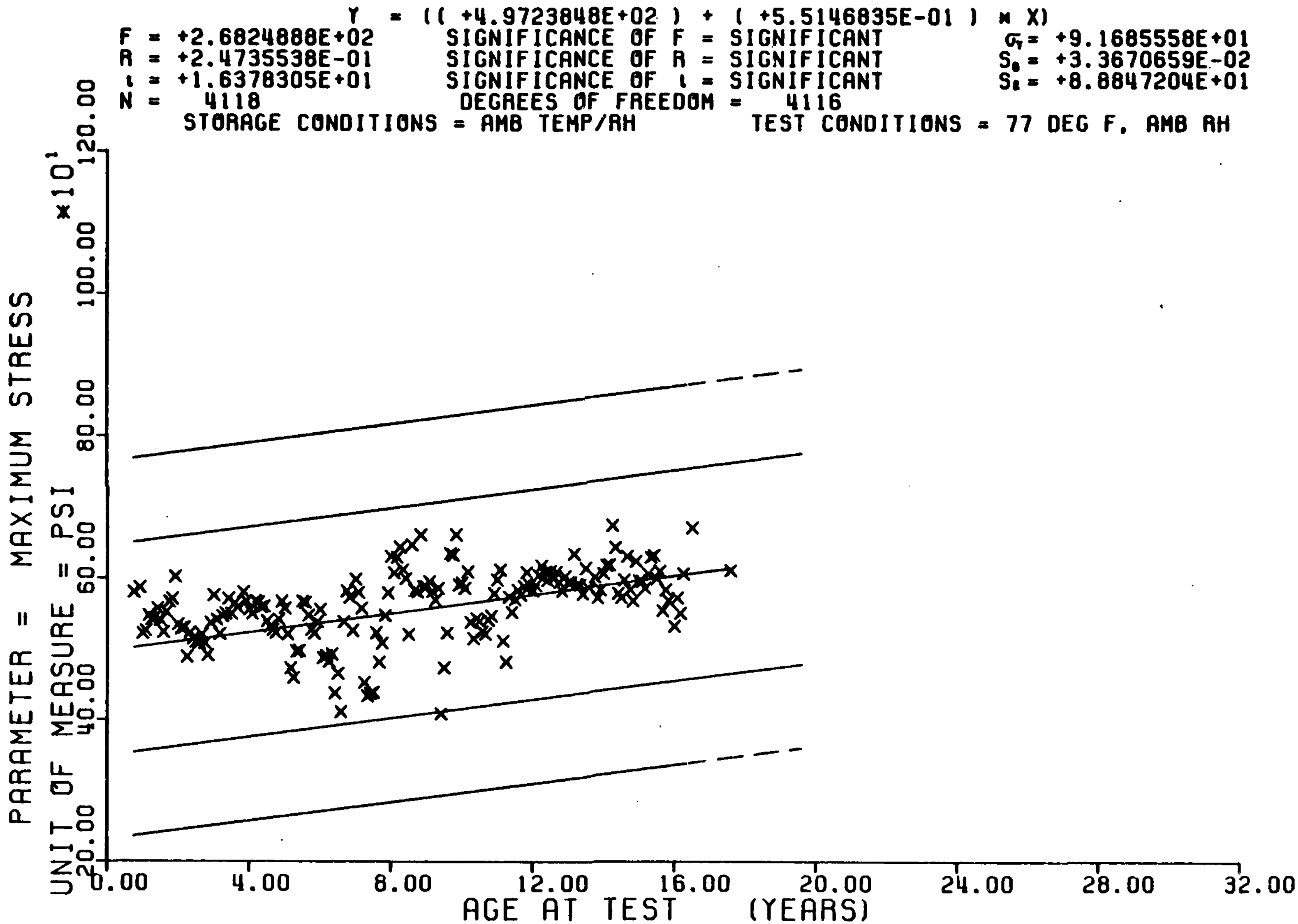
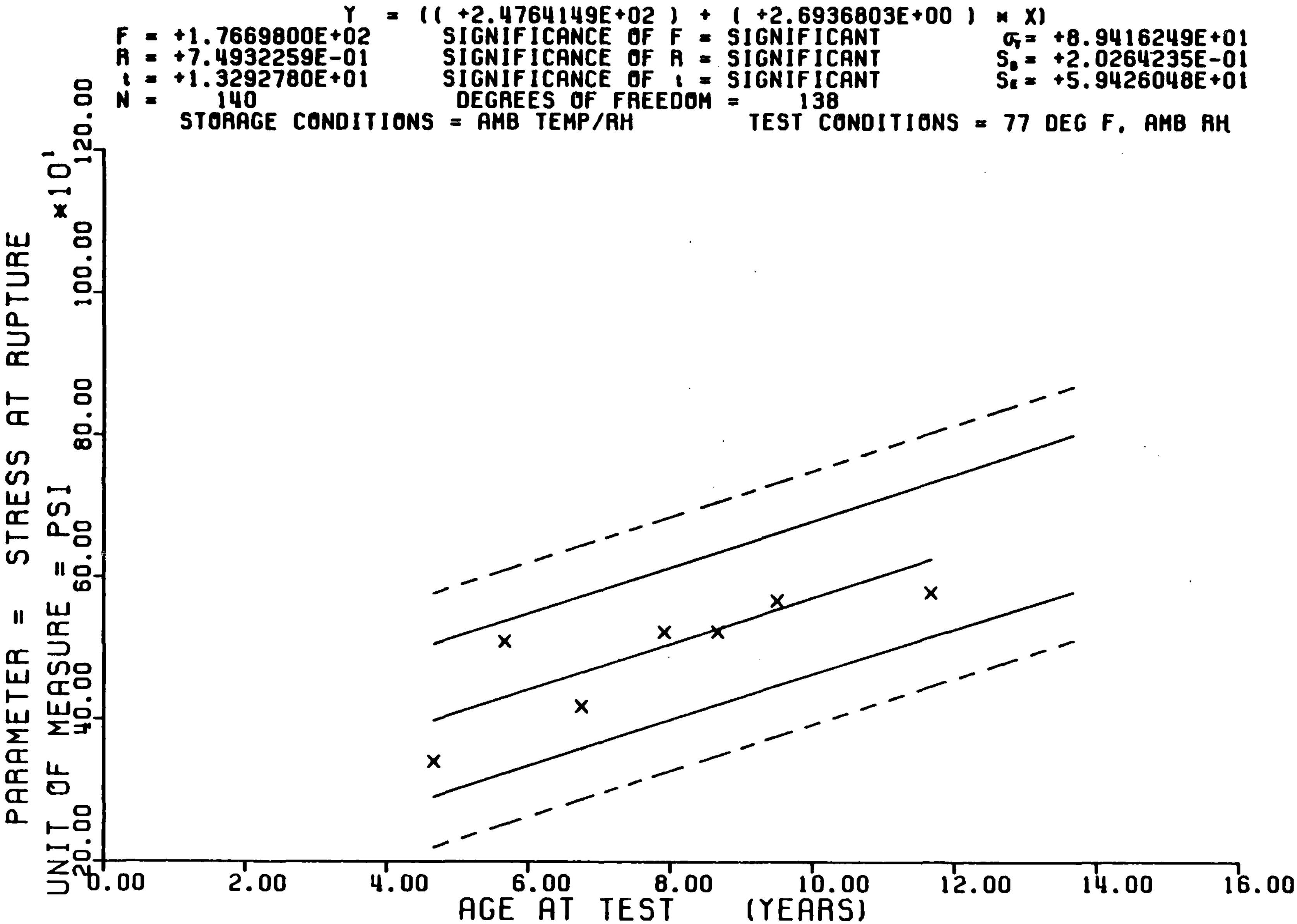

Y = (( +2.7089868E+02 ) + ( +2.8559667E+00 ) * X)
F = +1.9007516E+02 SIGNIFICANCE OF F = SIGNIFICANT σ = +9.3328947E+01
R = +7.6116009E-01 SIGNIFICANCE OF R = SIGNIFICANT S = +2.0715263E-01
ι = +1.3786774E+01 SIGNIFICANCE OF ι = SIGNIFICANT S = +6.0748714E+01
N = 140 DEGREES OF FREEDOM = 138
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH
PARAMETER = MAXIMUM STRESS
UNIT OF MEASURE = PSI
×10¹
20.00
40.00
60.00
80.00
100.00
120.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AGE AT TEST (YEARS)
HYDROSTATIC TENSILE, MAXIMUM STRESS, 800 PSI, 1750 IN/MIN, ACRYLIC ACID STUDY

Figure 21



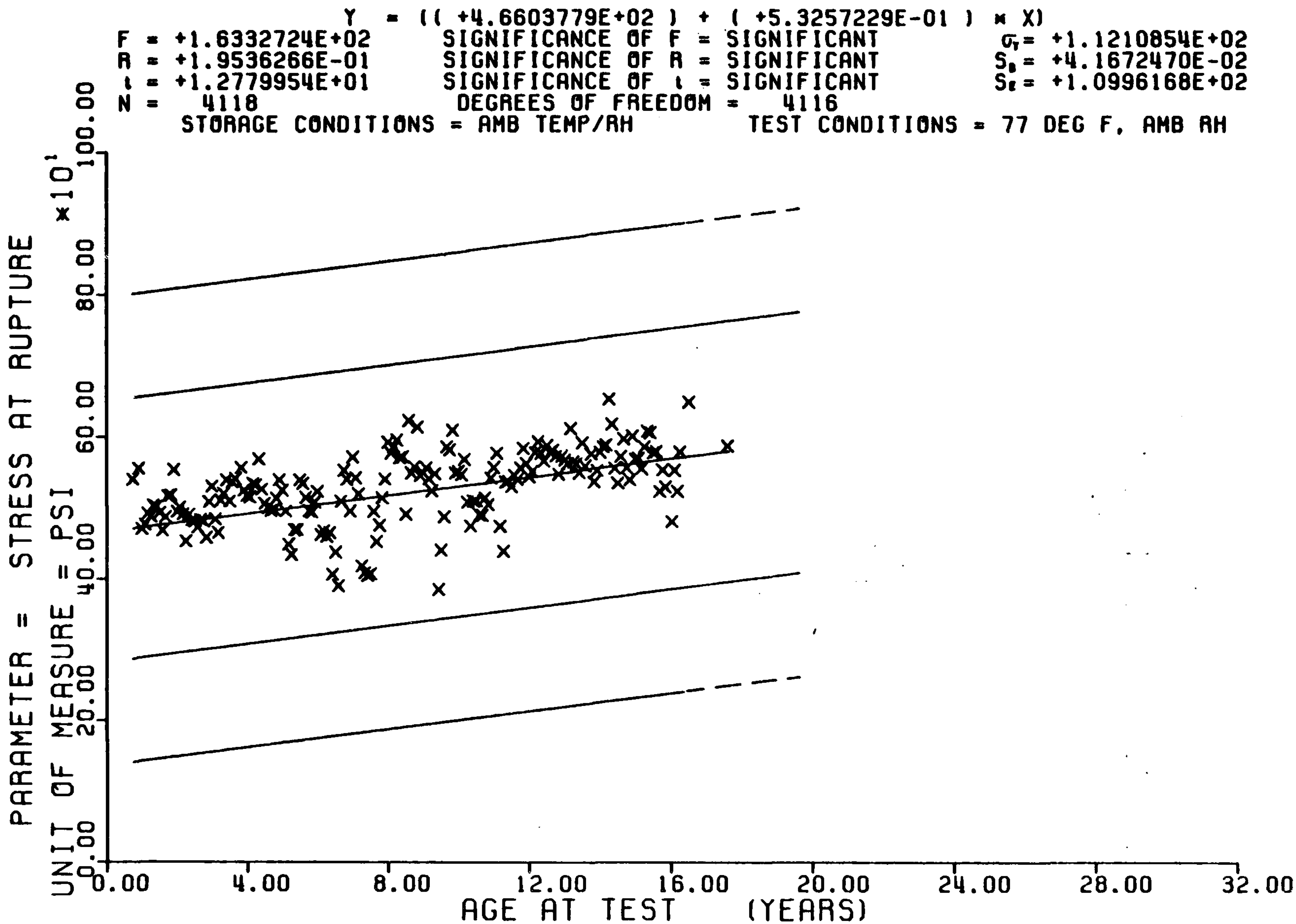

HYDROSTATIC TENSILE, MAXIMUM STRESS, WING 6 TP-H1011, 1750 IN/MIN, 800 PSI

Figure 22




HYDRO TENSILE, STRESS AT RUPTURE, 800 PSI, 1750 IN/MIN, ACRYLIC ACID STUDY

Figure 23




HYDROSTATIC TENSILE, STRESS AT RUPTURE, WING 6 TP-H1011, 1750 IN/MIN, 800 PSI

Figure 24

$Y = (( +4.1579466E-01 ) + ( -7.5420586E-04 ) \times X)$

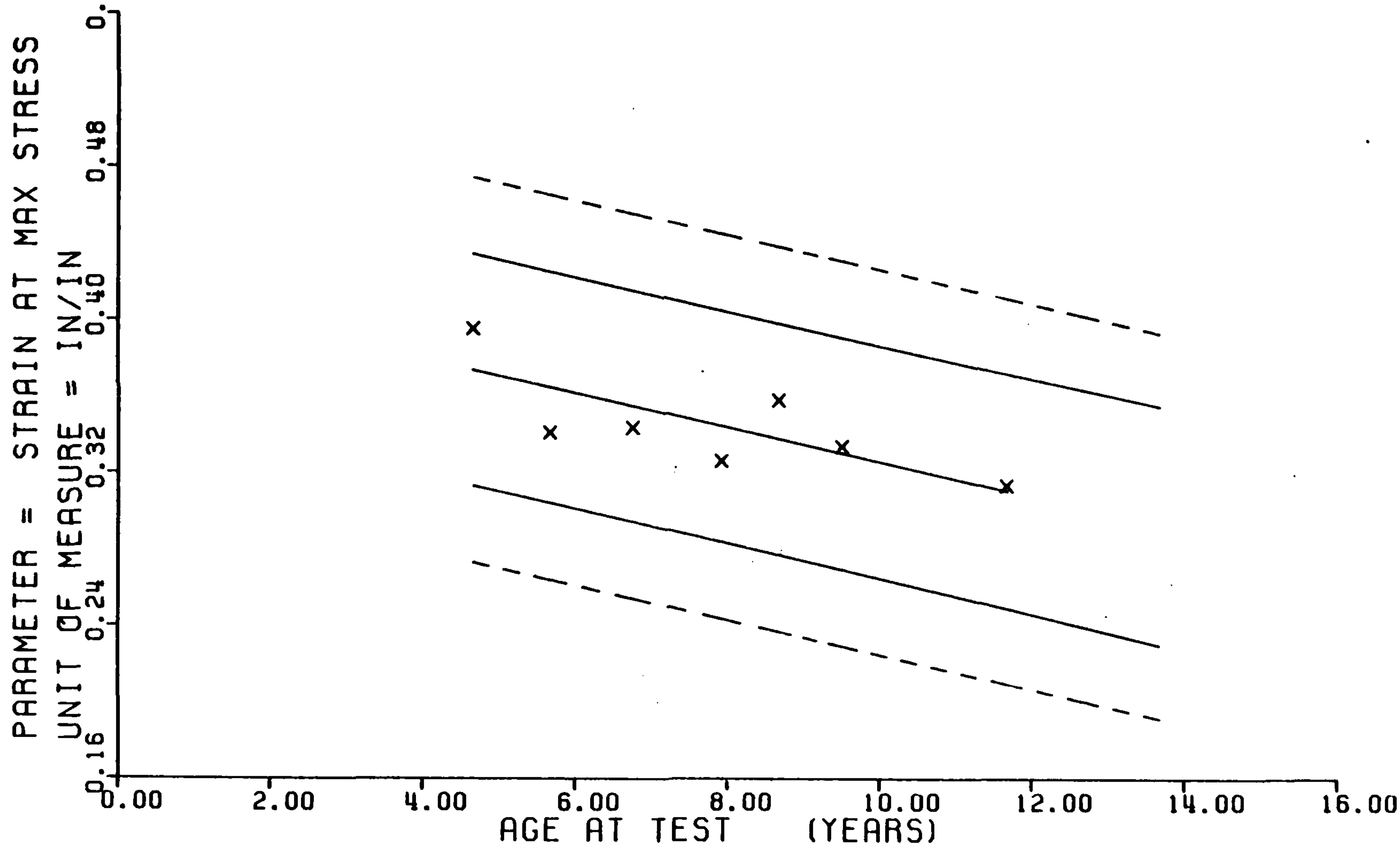
F = +4.3491065E+01 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_Y$ = +3.8322755E-02

R = -4.8952220E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_b$ = +1.1436414E-04

$t$ = +6.5947756E+00 SIGNIFICANCE OF $t$ = SIGNIFICANT $S_\varepsilon$ = +3.3537949E-02

N = 140 DEGREES OF FREEDOM = 138

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH




HYDRO TENSILE, STRAIN AT MAX STRESS, 800 PSI, 1750 IN/MIN, ACRYLIC ACID STUDY

Figure 25

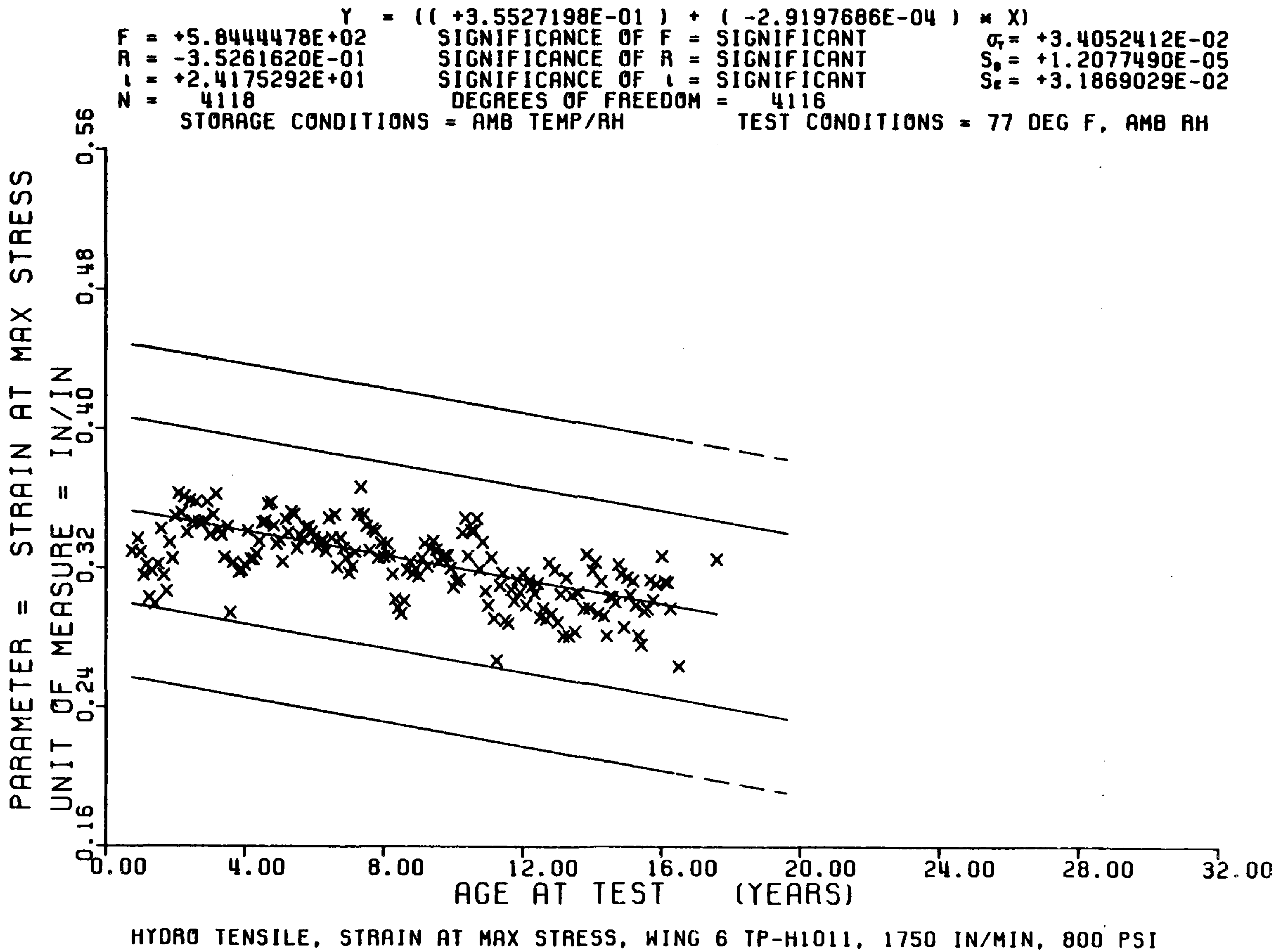

Y = (( +3.5527198E-01 ) + ( -2.9197686E-04 ) * X)
F = +5.8444478E+02 SIGNIFICANCE OF F = SIGNIFICANT
R = -3.5261620E-01 SIGNIFICANCE OF R = SIGNIFICANT
t = +2.4175292E+01 SIGNIFICANCE OF t = SIGNIFICANT
N = 4118 DEGREES OF FREEDOM = 4116
σY = +3.4052412E-02
Sb = +1.2077490E-05
Sε = +3.1869029E-02
STORAGE CONDITIONS = AMB TEMP/RH
TEST CONDITIONS = 77 DEG F, AMB RH
PARAMETER = STRAIN AT MAX STRESS
UNIT OF MEASURE = IN/IN
0.56
0.48
0.40
0.32
0.24
0.16
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
HYDRO TENSILE, STRAIN AT MAX STRESS, WING 6 TP-H1011, 1750 IN/MIN, 800 PSI

Figure 26

Y = (( +4.8742496E-01 ) + ( -6.7697922E-04 ) * X)

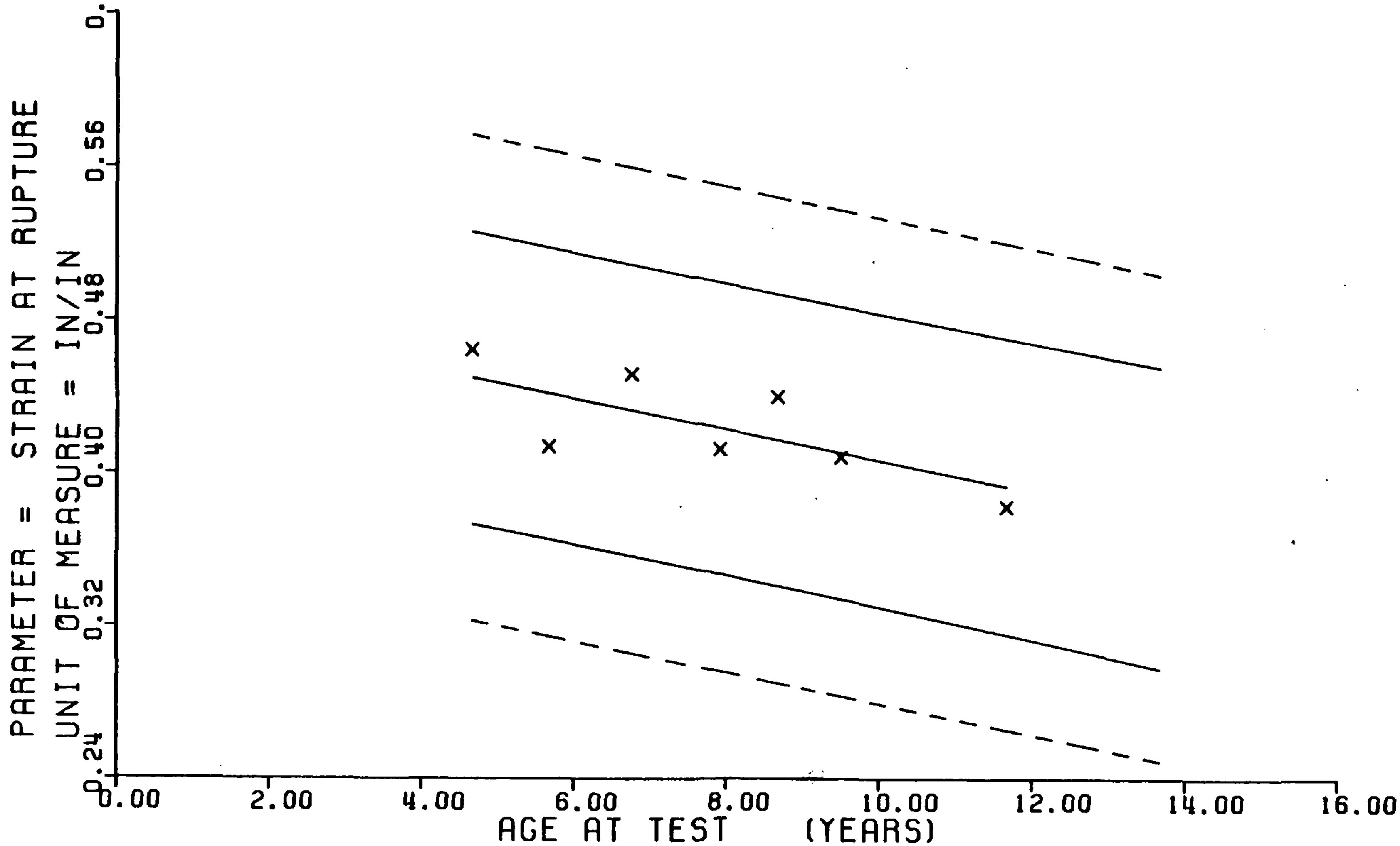
F = +2.2011929E+01 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_Y$ = +4.5400611E-02

R = -3.7089661E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_B$ = +1.4429334E-04

t = +4.6916872E+00 SIGNIFICANCE OF t = SIGNIFICANT $S_E$ = +4.2314860E-02

N = 140 DEGREES OF FREEDOM = 138

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH

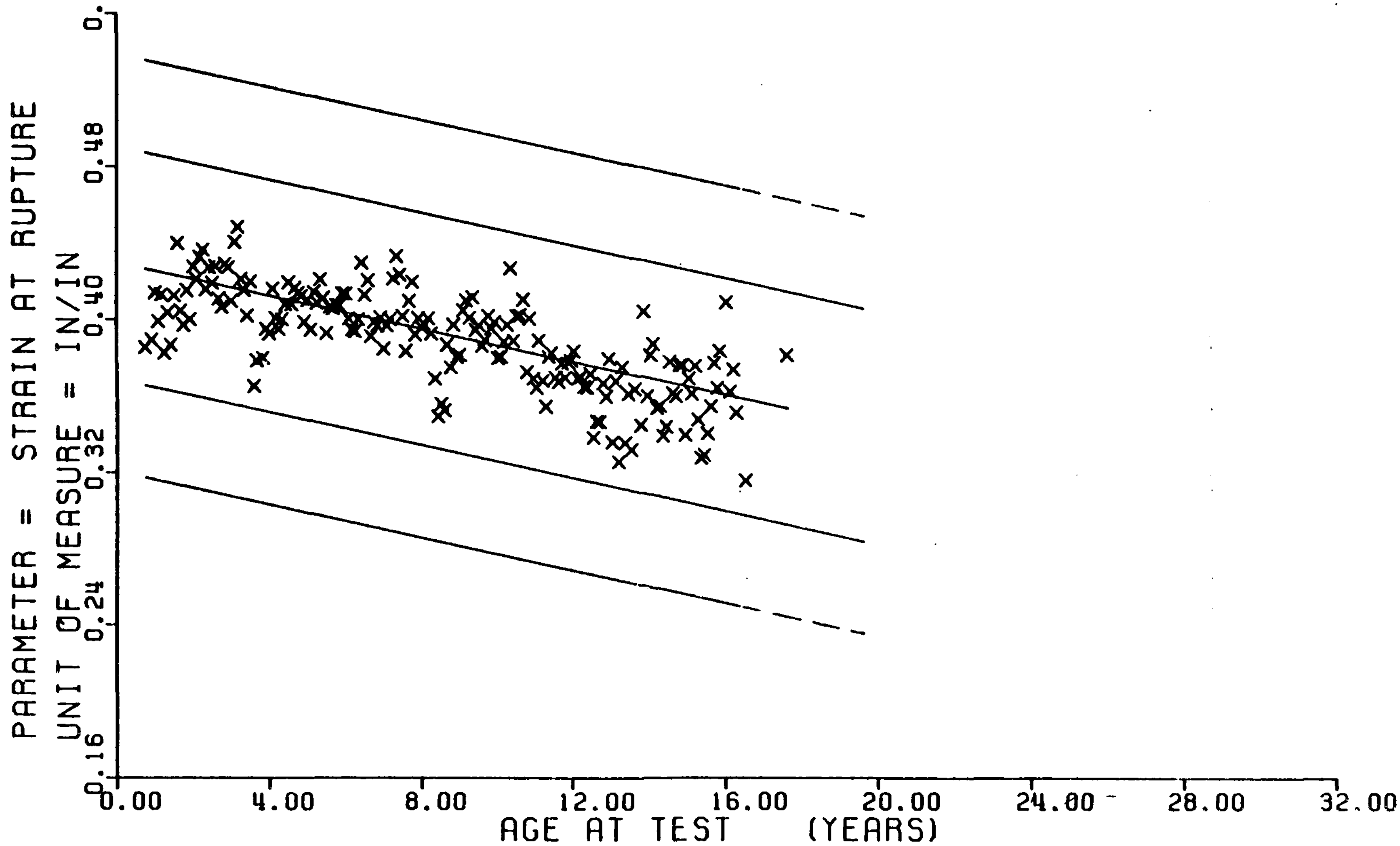



HYDRO TENSILE, STRAIN AT RUPTURE, 800 PSI, 1750 IN/MIN, ACRYLIC ACID STUDY

Figure 27

$$Y = ((+4.2966568E-01) + (-3.6195597E-04) * X)$$

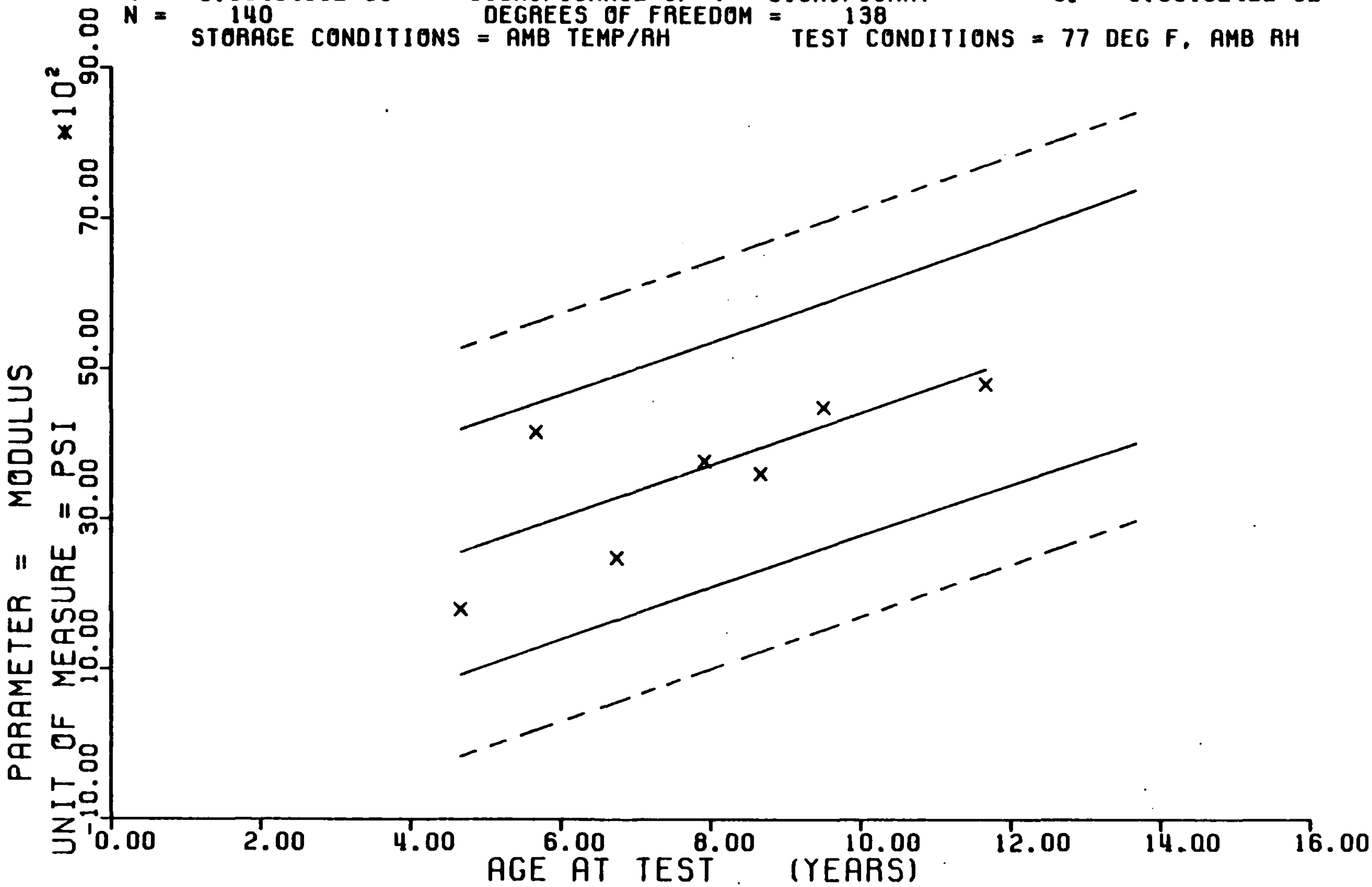
F = +6.8931742E+02 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_Y$ = +3.9288927E-02
R = -3.7882530E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_B$ = +1.3786248E-05
$t$ = +2.6254855E+01 SIGNIFICANCE OF $t$ = SIGNIFICANT $S_E$ = +3.6365071E-02
N = 4116 DEGREES OF FREEDOM = 4114
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH




HYDROSTATIC TENSILE, STRAIN AT RUPTURE, WING 6 TP-H1011, 1750 IN/MIN, 800 PSI

Figure 28

Y = (( +9.3203031E+02 ) + ( +2.8996471E+01 ) × X)
F = +8.8264914E+01 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_Y$ = +1.1547791E+03
R = +6.2457621E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_B$ = +3.0863921E+00
$\iota$ = +9.3949408E+00 SIGNIFICANCE OF $\iota$ = SIGNIFICANT $S_E$ = +9.0510242E+02
N = 140 DEGREES OF FREEDOM = 138
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH




HYDROSTATIC TENSILE, MODULUS, 800 PSI, 1750 IN/MIN, ACRYLIC ACID STUDY

Figure 29

Y = (( +3.3628553E+03 ) + ( +6.5331281E+00 ) * X)

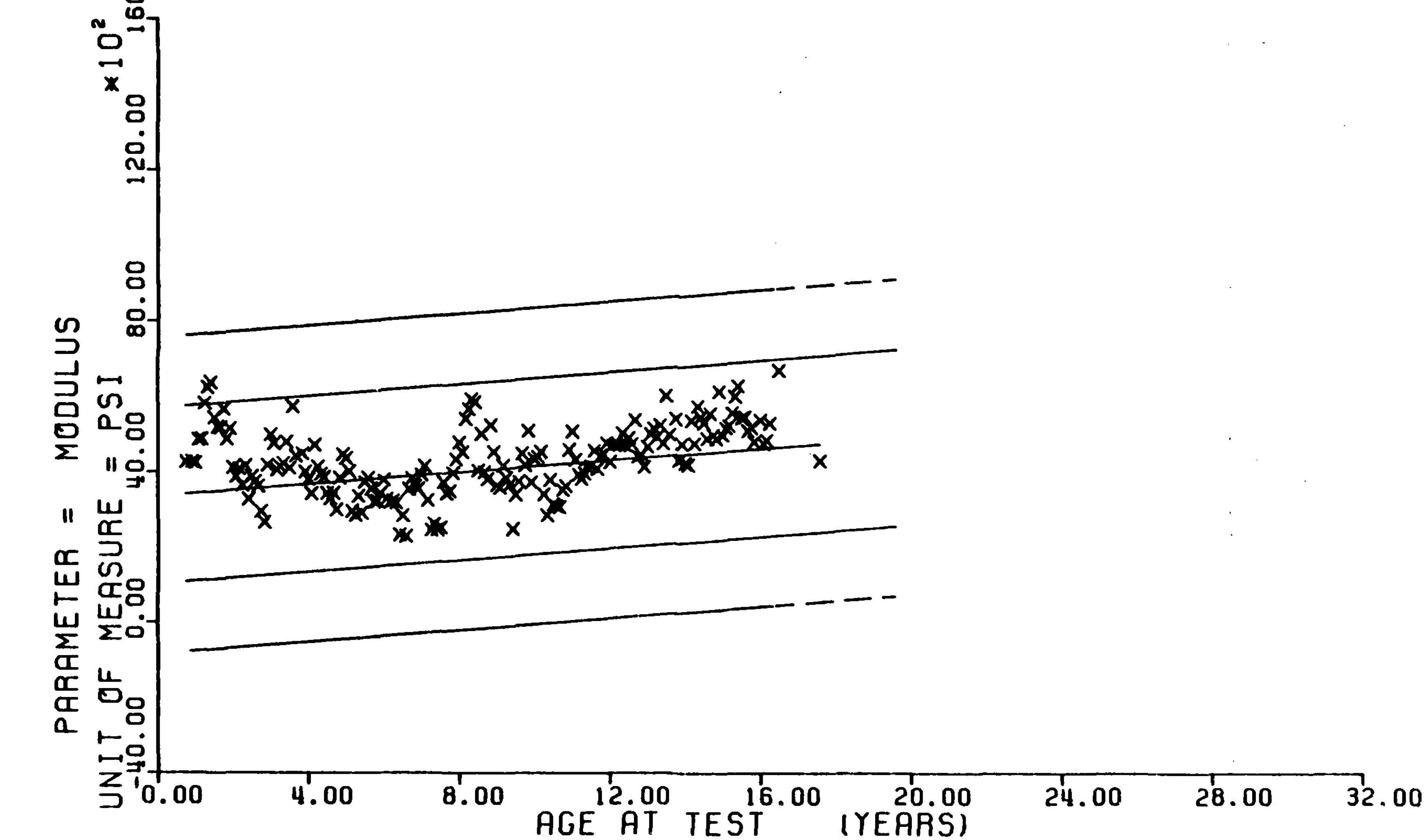
F = +1.5155450E+02 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_T$ = +1.4256213E+03

R = +1.8847153E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_b$ = +5.3068493E-01

t = +1.2310747E+01 SIGNIFICANCE OF t = SIGNIFICANT $S_E$ = +1.4002423E+03

N = 4117 DEGREES OF FREEDOM = 4115

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH



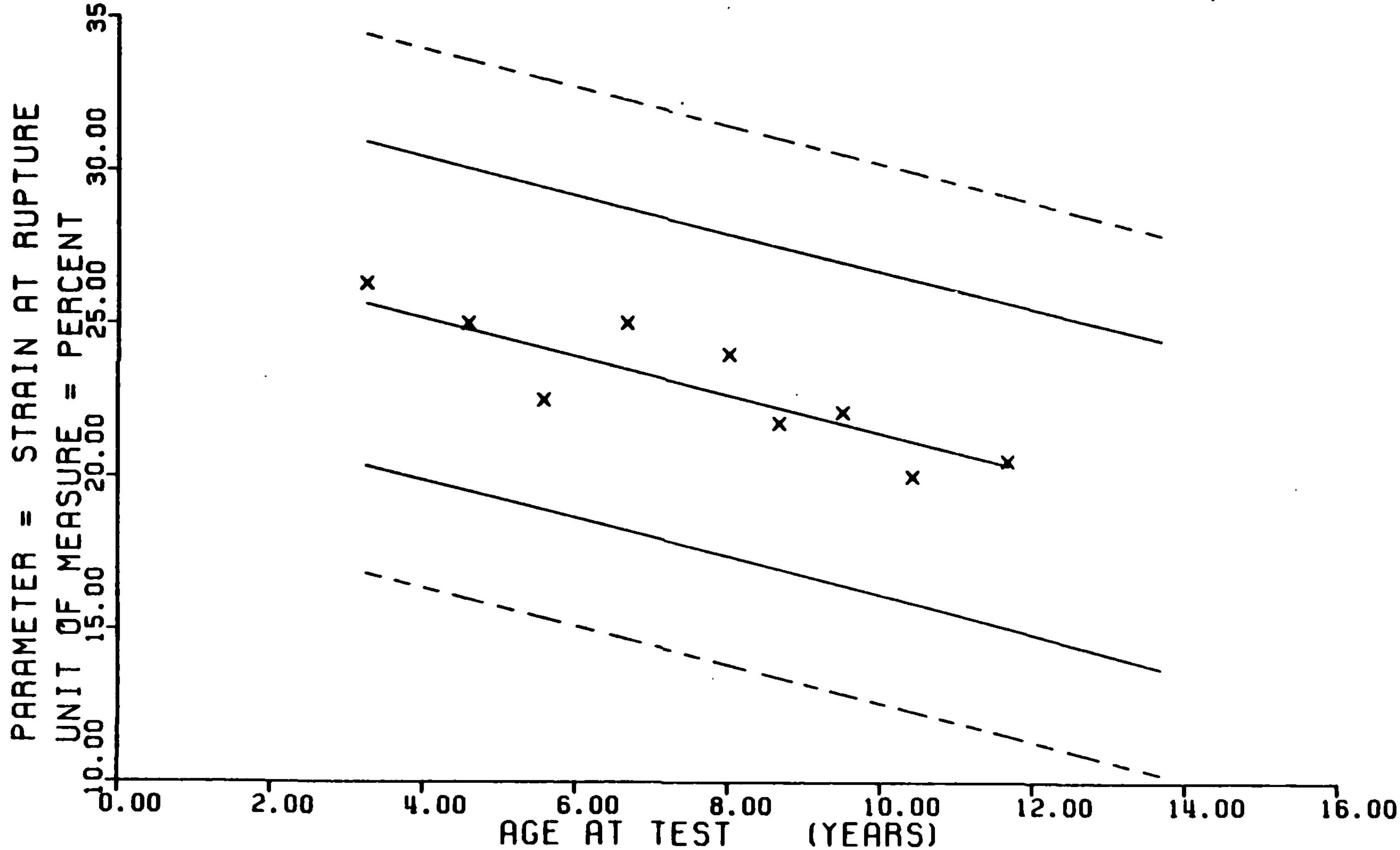

HYDROSTATIC TENSILE, MODULUS, WING 6 TP-H1011 PROPELLANT, 1750 IN/MIN, 800 PSI

Figure 30

Y = (( +2.7677801E+01 ) + ( -5.2322331E-02 ) × X)

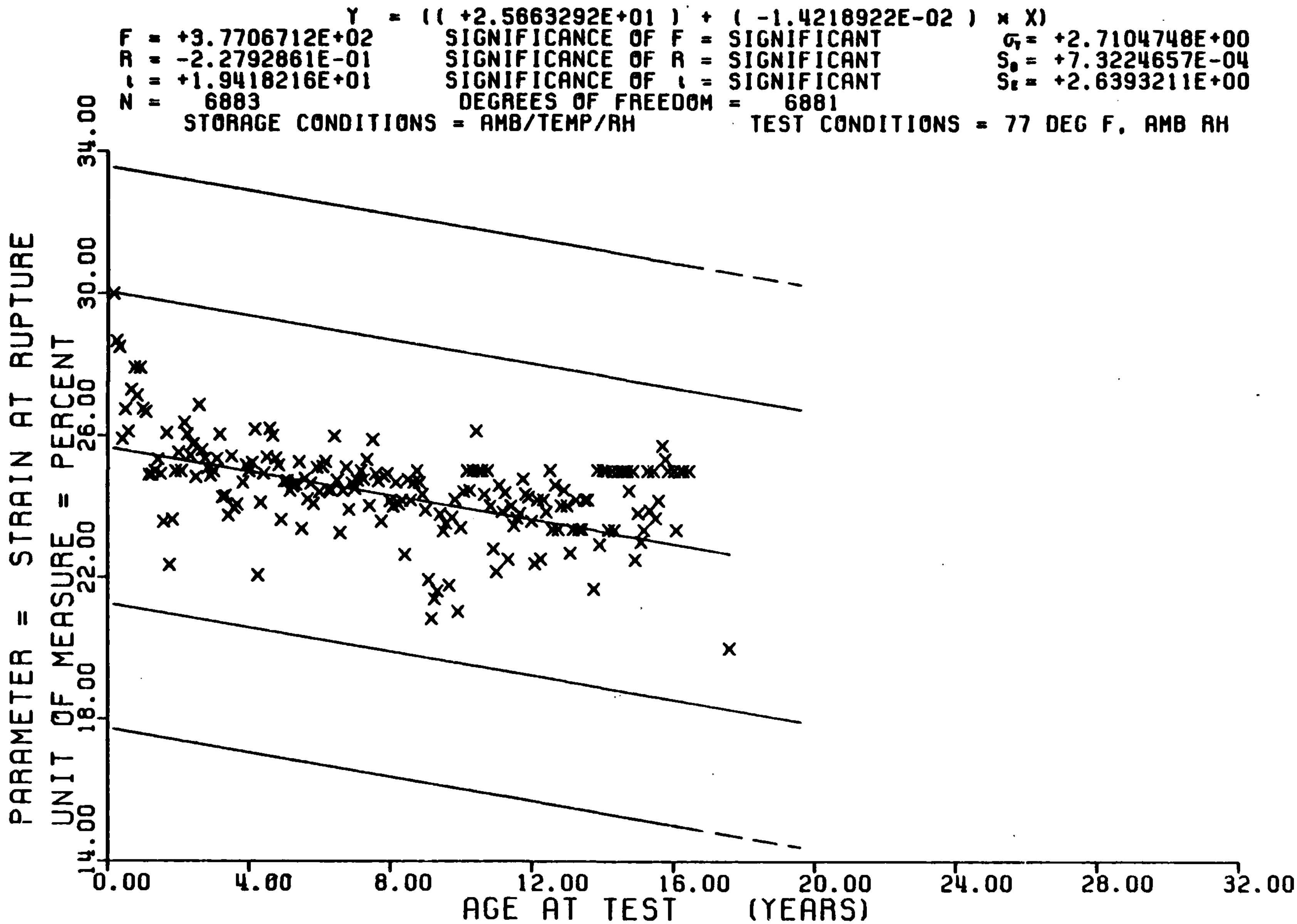
F = +4.4314322E+01 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_T$ = +3.3244087E+00
R = -4.7511207E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_B$ = +7.8598640E-03
$\iota$ = +6.6569003E+00 SIGNIFICANCE OF $\iota$ = SIGNIFICANT $S_E$ = +2.9348380E+00
N = 154 DEGREES OF FREEDOM = 152

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH




CONSTANT STRAIN, STRAIN AT RUPTURE, ACRYLIC ACID STUDY

Figure 31




CONSTANT STRAIN, STRAIN AT RUPTURE, WING 6 TP-H1011 CARTON PROPELLANT

Figure 32

Y = (( +1.1563432E+00 ) + ( -7.4726634E-04 ) * X)

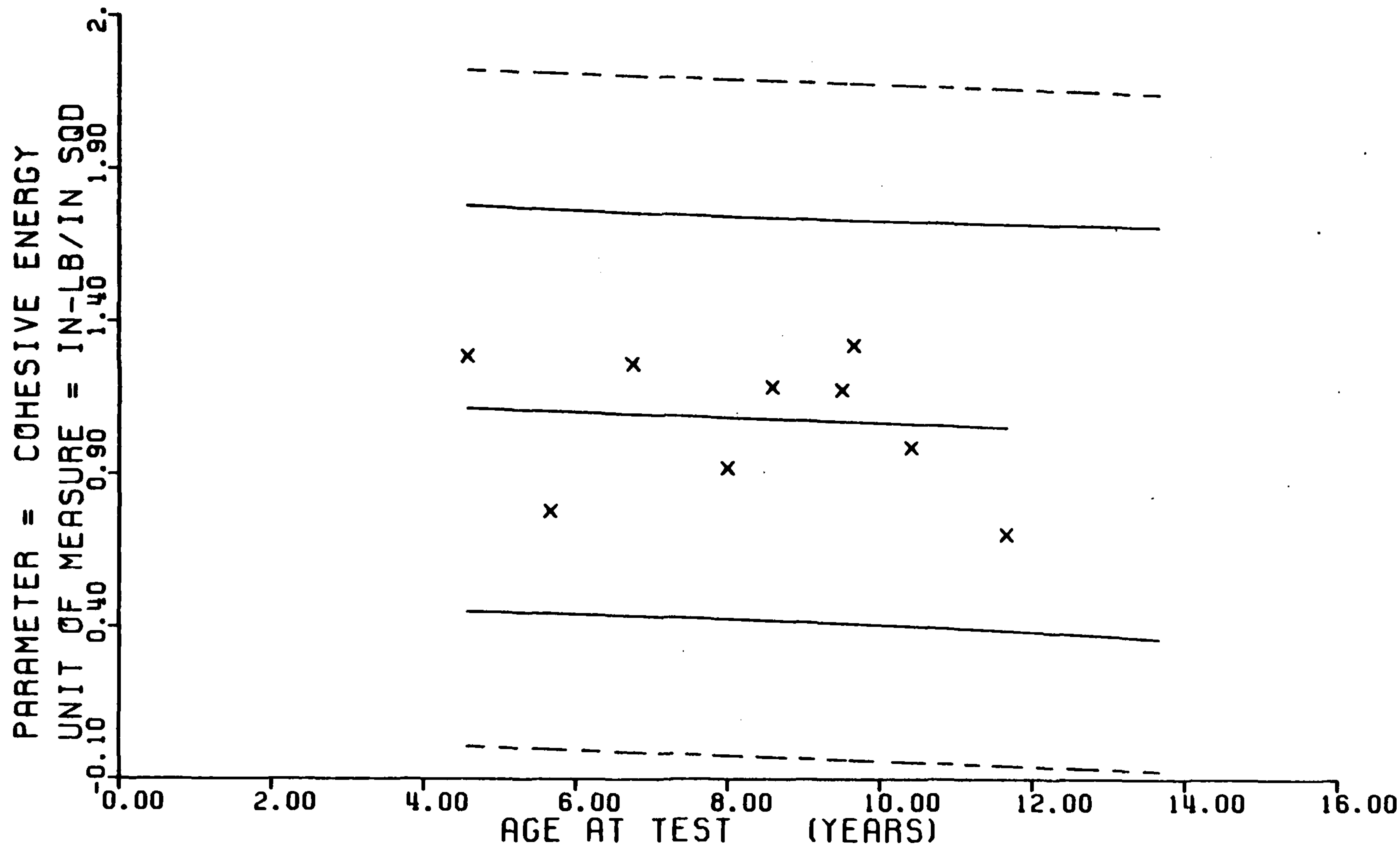
F = +3.9399837E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT $\sigma_Y$ = +3.6850688E-01

R = -4.9717723E-02 SIGNIFICANCE OF R = NOT SIGNIFICANT $S_B$ = +1.1904967E-03

t = +6.2769289E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT $S_E$ = +3.6920673E-01

N = 161 DEGREES OF FREEDOM = 159

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH



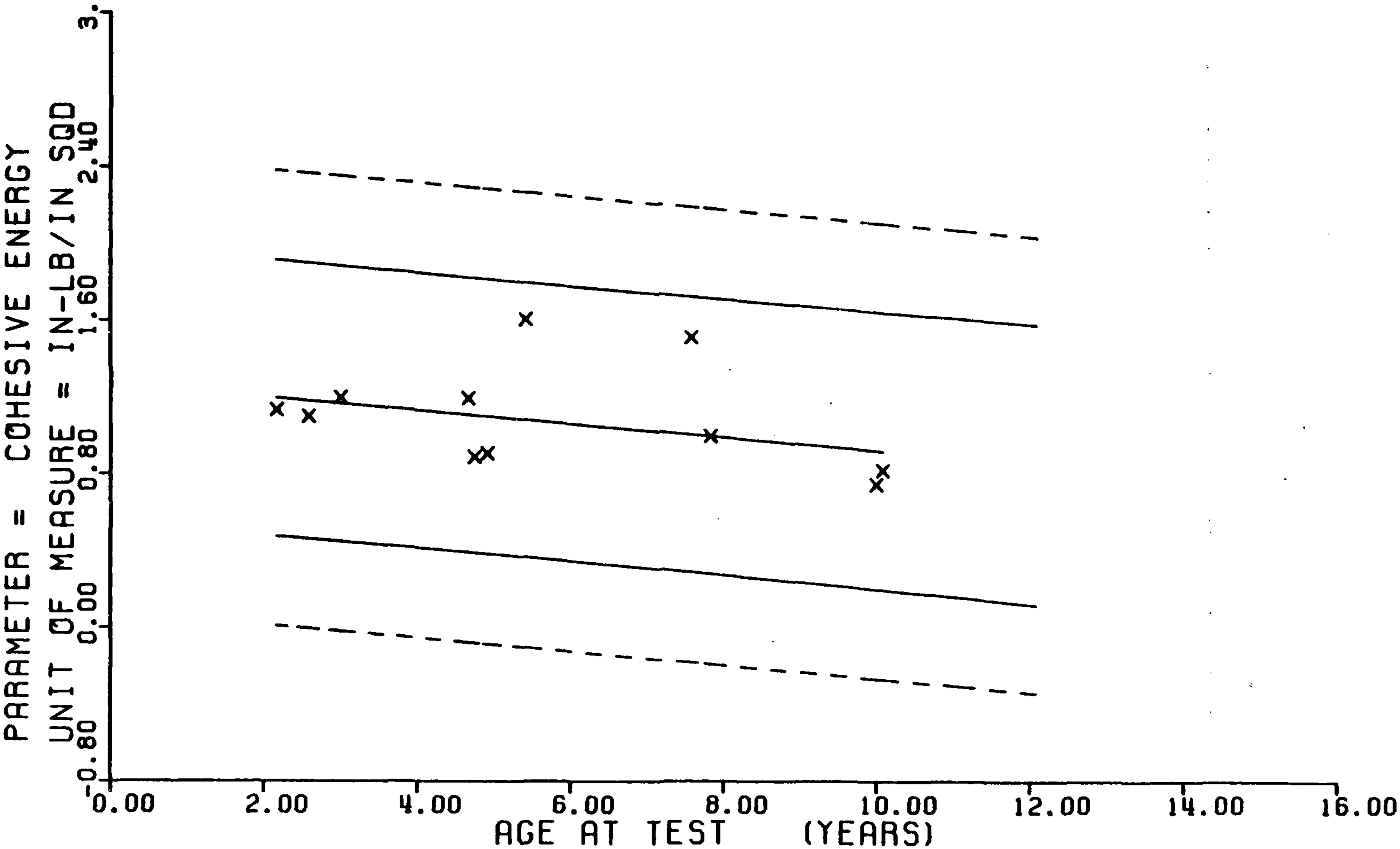

TEAR ENERGY, COHESIVE ENERGY AT 0.1 IN/MIN, ACRYLIC ACID STUDY

Figure 33

Y = (( +1.2718053E+00 ) + ( -2.9404487E-03 ) * X)

F = +7.3959993E+00 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_Y$ = +4.0501268E-01
R = -2.3815861E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_B$ = +1.0812227E-03
t = +2.7195586E+00 SIGNIFICANCE OF t = SIGNIFICANT $S_E$ = +3.9495474E-01
N = 125 DEGREES OF FREEDOM = 123

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH




TEAR ENERGY TEST, COHESIVE ENERGY, WING 6 TP-H1011 CARTON SAMPLING, 0.1 IN/MIN

Figure 34

Y = (( +2.4961449E+01 ) + ( +3.1926939E-01 ) * X)

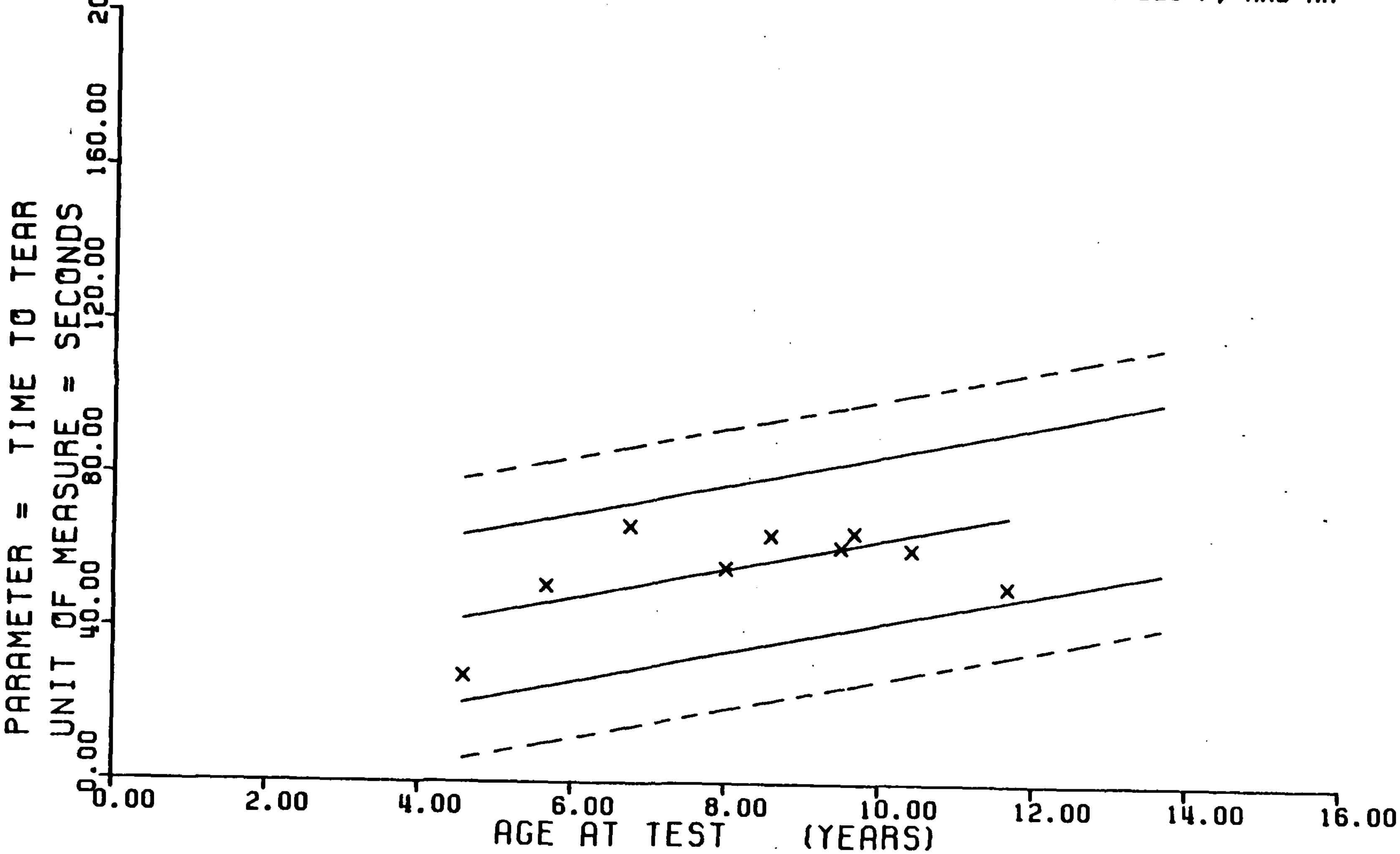
F = +6.6478752E+01 SIGNIFICANCE OF F = SIGNIFICANT $\sigma_Y$ = +1.4416176E+01

R = +5.4298598E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_B$ = +3.9157581E-02

t = +8.1534503E+00 SIGNIFICANCE OF t = SIGNIFICANT $S_E$ = +1.2143874E+01

N = 161 DEGREES OF FREEDOM = 159

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH



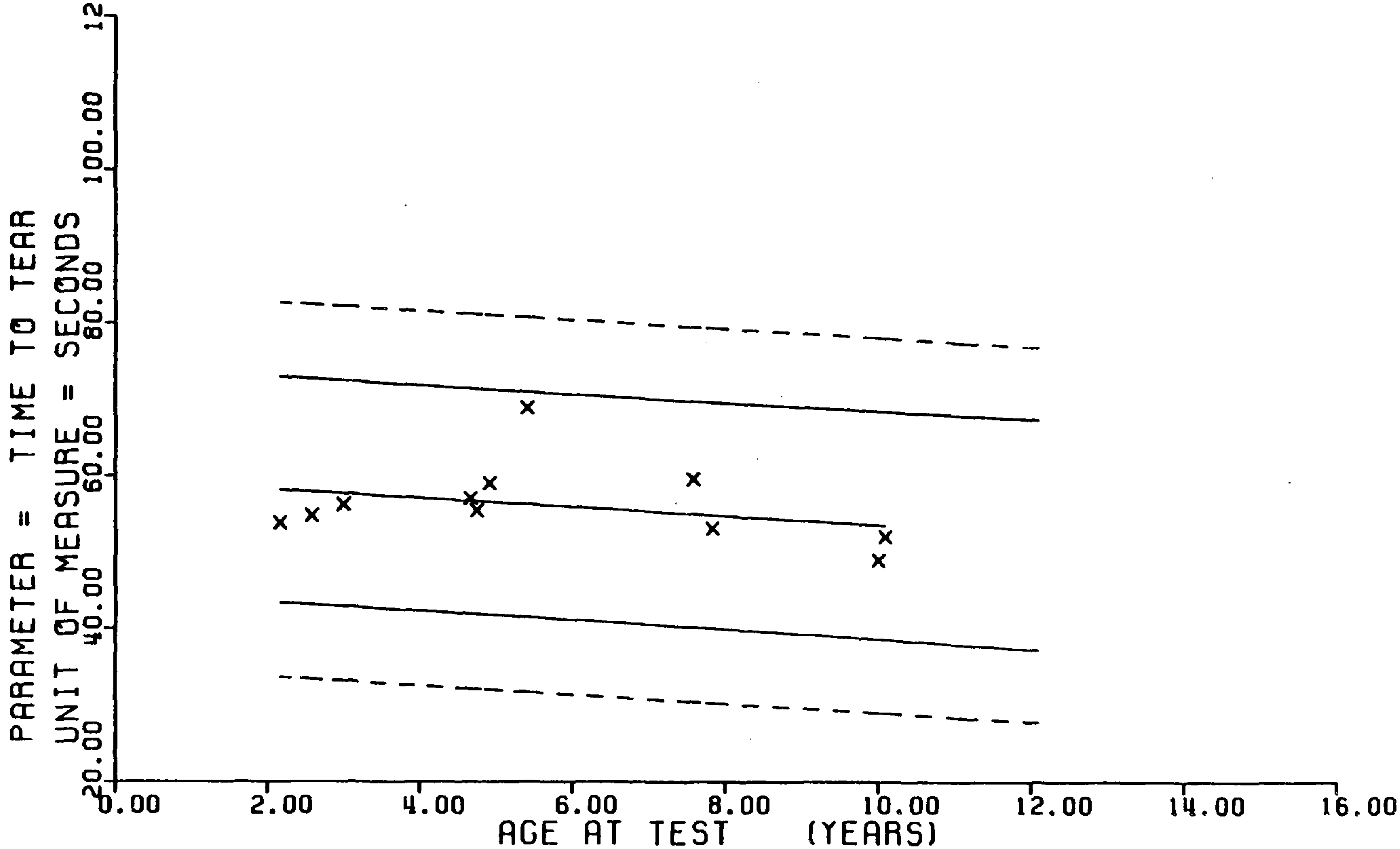

TEAR ENERGY, TIME TO TEAR AT 0.1 IN/MIN, ACRYLIC ACID STUDY

Figure 35

Y = (( +5.9432031E+01 ) + ( -4.9789448E-02 ) * X)

F = +4.9770174E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT $\sigma_Y$ = +8.2820918E+00
R = -1.9720530E-01 SIGNIFICANCE OF R = SIGNIFICANT $S_B$ = +2.2317869E-02
$\iota$ = +2.2309230E+00 SIGNIFICANCE OF $\iota$ = SIGNIFICANT $S_E$ = +8.1523890E+00
N = 125 DEGREES OF FREEDOM = 123

STORAGE CONDITIONS = AMB/TEMP/RH TEST CONDITIONS = 77 DEG F, AMB RH




TEAR ENERGY TEST, TIME TO TEAR, WING 6 TP-H1011 CARTON PROPELLANT, 0.1 IN/MIN

Figure 36

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Minuteman
Glacial Acrylic Acid

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Thiokol Minuteman First Stage propellant used acrylic acid to produce the HB polymer used as the binder. The original supplier of acrylic acid stopped production and Thiokol then obtained acrylic acid produced by the Taft, Louisiana Plant of Union Carbide Company (UCC).

To assure that this new source of supply was a satisfactory replacement, Thiokol* ran qualification testing on the new material and found it satisfactory. In the Thiokol* program two motors were cast in 1971 and propellant from the

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mixes were cast into cartons for a ten year test program. This propellant was then transferred to this laboratory and testing on a yearly basis was started in 1975.

Due to insufficient propellant, the full ten year program was not possible. Testing was completed after nine years and this is the final report.

From an analysis of the data the propellant's physical properties are satisfactory and the stability, with respect to age, is satisfactory.

*Final report evaluation of HB polymer manufactured using Taft glacial acrylic acid. Report number TWR-4716, May 1972. Thiokol/Wasatch Division, a division of Thiokol Chemical Corporation.

END

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